

Reply to Anonymous Referee #1

Specific comments

1. While generally well-written the paper contains numerous small English language errors which need to be corrected. I have pointed out many (hopefully most) of these below under technical errors.

We apologize for the numerous small English language errors. Some of them are certainly because we are not native English speakers, but we agree that quite many of them would have been avoidable. Many thanks for carefully pointing out the many corrections, all of which we of course incorporated in the revised version.

2. It would be helpful if a few more sentences could be added on the difference between this version of LAGRANTO and previous version(s). Are the differences just those described as the ‘enhanced functionalities’ in the abstract or do other differences exist? Would this version of LAGRANTO produce exactly the same trajectory set as the previous version for an example case (given the same starting positions etc.).

Indeed, nothing has been said about a comparison between the previous and the new version in the manuscript. Of course, many tests have been performed during the development of the new version. One of the powerful tests was as follows: forward trajectories are calculated 48 h forward in time (at any time, e.g., from 00 UTC 1 Jan 2014 to 00 UTC 3 Jan 2014) starting on a globally equidistant grid (80 km horizontal spacing) at 500 hPa (79539 trajectories in total). The jumping flag was set to handle crossings of the lower boundary and potential vorticity (PV) was traced along the trajectories. Then, the air parcel positions were compared (as spherical distances in km) between the calculation based on the previous Lagranto version and the new one. The positions of the two trajectory calculations turn out to be exactly the same, with the single exception of one trajectory that starts exactly at the North Pole. Furthermore, the PV values traced along the trajectories do also agree very well, with most differences below 0.001 PVU. In summary, the two versions of Lagranto result in essentially exactly the same forward trajectories. As an additional test, we repeated the procedure outlined above for backward trajectories leading to the same conclusion: both Lagranto versions result in the same output. Of course, this result is not astonishing because the time step and interpolation methods are 1-to-1 taken from the previous Lagranto version.

We could include these test results in the manuscript, but would prefer not to do so in great detail. The test/comparison itself is of course very important to users familiar with the previous version of Lagranto, but does not add any value for potential new users. Therefore, we only briefly mention in the manuscript that the two calculations agree. More specifically, we entered the following short paragraph at the end of section 3.3:

“Consistency with LAGRANTO 1.0: The new version of LAGRANTO uses the same bilinear interpolation and time-stepping scheme as LAGRANTO 1.0. Therefore, a perfect agreement is expected if the same starting positions and wind fields are used. Indeed, we performed such a comparison for 48-h forward and backward trajectories, started on a global grid at 500 hPa. All of the trajectories, 79539 in total, agreed perfectly in position and differences for variables traced along the trajectories (e.g., PV and TH) remained negligible.”

3. Several other trajectory tools are mentioned in the introduction. In the conclusion 3 special features of LAGRANTO compared to other trajectory tools are listed. Can you be more precise as to whether any of the other trajectory tools you’ve mentioned incorporate any of these special features i.e. if the user required one of these special features is LAGRANTO the only option?

To the best of our knowledge these specific features are unique to Lagranto – or at least they would require additional programming efforts for the user working with another trajectory tool.

Technical corrections

1. Abstract: the second sentence of the abstract covers a whole 11 lines and the use of semicolons doesn’t seem quite right. It would be better just to use them to distinguish the list labels i.e. prior to (ii) and (iii) and to use other punctuation (commas or brackets) to separate other items. Alternatively it would improve readability to separate this long sentence into multiple sentences.

The abstract has been rewritten to increase readability. It now reads:

Lagrangian trajectories are widely used in the atmospheric sciences, for instance to identify flow structures in extratropical cyclones (e.g., warm conveyor belts) and long-range transport pathways of moisture and trace substances. Here a new version of the Lagrangian analysis tool LAGRANTO (Wernli and Davies, 1997) is introduced, which offers considerably enhanced functionalities. Trajectory starting positions can be defined easily and flexibly based on different geometrical and/or meteorological conditions; e.g., equidistantly spaced within a prescribed region and on a stack of pressure (or isentropic) levels. After the computation of the trajectories, a versatile selection of trajectories is offered based on single or combined criteria. These criteria are passed to LAGRANTO with a simple command language (e.g., “GT:PV:2” readily translates into a selection of all trajectories with potential vorticity (PV) greater than 2 PVU). Full versions of this new version of LAGRANTO are available for global ECMWF and regional COSMO data, and core functionality is provided for the regional WRF and UM models and the global 20th Century Reanalysis data set. The paper first presents the intuitive application of LAGRANTO for the identification of a warm conveyor belt in the North Atlantic. A further case study then shows how LAGRANTO can be used to quasi-operationally diagnose stratosphere–troposphere exchange events. Whereas these examples rely on the ECMWF version, the COSMO version and input fields with 7 km horizontal resolution serve to resolve the rather complex flow structure associated with orographic blocking due to the Alps, as shown in a third example. A final example illustrates the tool’s application in source-receptor analysis studies. The new distribution of LAGRANTO is publicly available and includes auxiliary tools, e.g., to visualize and merge trajectories. A detailed user guide describes all LAGRANTO capabilities.

2. UM should be changed to MetUM throughout the text as this is the standard acronym for this model.

done

3. Abstract L18: ‘example’ -> ‘examples’

done

4. Abstract: I found this difficult to follow in terms of the example cases initially as it isn’t immediately obvious that orographic blocking is one of the examples in the paper (which makes the reference to the resolution needed to represent this rather meaningless). A simple change in L19 to ‘. . . are needed for the next example to adequately. . .’ would improve this.

This should be better now with the improved version of the abstract (see reply to comment 1).

5. p1896, L1: ‘application’ -> ‘applications’

done

6. p1896, L25: change to ‘LAGRANTO was first used. . .’

done

7. p1897, L4: ‘helped analyzing’ -> ‘helped analyze’

done

8. p1897, L16: I’d remove the comma after ‘themes’

done

9. p1998, L2 and elsewhere: The colon is not usually used in times in Met. papers (i.e. 1200 UTC rather than 12:00 UTC) so I suggest changing this unless the convention is different for this journal.

done

10. p1898, L14: ‘available in netCDF..’ rather than ‘available on netCDF..’

done

11. p1898, L26: Strictly, the suffix .eqd tells LAGRANTO that the starting positions should be equidistantly distributed within the box with a spacing of 80km 'in this example' (rather than generally).

We now mention that it only applies to this example

12. 1898, L28: change to '. . . equidistant pressure levels. . .'

done

13. p1899, L18: you say that the input files could in principle be available every minute, have you tested that this works?

Indeed members of our group are calculating trajectories based on input files available at a time interval as short as a few minutes. Actually an initial test first produced several problems, of course! But after correcting some errors in the shell scripts, LAGRANTO ran with these input files. The major step was to get a time interval shorter than 1 h. In the current version of LAGRANTO, the time handling should work down to 1 min.

14. p1900, L2: I don't understand the relevance of the sentence starting 'Note. . .'. What do you mean by 'the entries are not separated by an empty line'? What are the 'entries' in this case?

We decided to remove these two sentences from the manuscript. Basically, the point was rather technical: If you create a start file, it will also be a trajectory file, but a strange one if you use format 1. It only contains time, longitude, latitude and pressure for each starting position, followed by an empty line separating the first trajectory (starting position) from the next one. If format 2 is used instead, no extra empty line will be written between all the starting position, and the file will hence be more compact. The reviewer is perfectly right that the explanation in the submitted manuscript is not clear enough; on the other hand, a more thorough explanation would need too much text given the minor importance of this little item.

15. p1900, L6 and in lots of other places: The verb 'allow' is used incorrectly throughout this article. For example here instead of 'which allows to trace meteorological fields' you should use 'which allows one to trace meteorological fields' or, probably better, 'allows meteorological fields to be traced. . .'

Many thanks for hinting to this language problem. Searching for 'allow' in the text, indeed it turns out that we use it rather often. We have corrected all instances, if possible with the better version mentioned by the reviewer.

16. p1901, L11: change to 'A well-established WCB can be. . .'

done

17. p1901, L12: change to 'near the surface'

done

18. p1902, 13: 'ECMWF is given' ?

done

19. p1902, L20: It took me a while to work out that (i) referred back to 'ECMWF hybrid sigma-p level type' – perhaps better to say this explicitly.

done

20. p1905, L17: 'fix' -> 'fixed'

done

21. p1905, L18: change to 'proceed on its course'

done

22. p1906, L16: spelling of ‘calculation’ is incorrect.

done

23. p1906, L24: This should be ‘parcels’ position’ since the position belongs to the parcels.

done

24. p1906, L25: change to ‘surroundings’

done

25. p1907, L12: ‘being part in both sets’ -> ‘that are part of both sets’

done

26. p1908, L15: ‘a field’ -> ‘this field’ since you are referring to field RTOT in this example.

done

27. p1908, L15: ‘it’s. . .’ ‘its’

done

28. p1910, L10: Why can the command ‘ALL’ only be applied with the label field of ‘select’? Table 2 lists examples without the label field.

'ALL' can be applied at two places of a selection criterion. If the general structure is {command:field:parameters:time}, then the first usage of 'ALL' is in the time specification (as in Table 2). There it means that all times listed before are used for the evaluation. On the other hand, if 'ALL' comes right in the beginning, i.e., as a command, then it has a completely different meaning. Here it only applies to the label feature of select and means that labels must be set simultaneously. An option would be to more clearly distinguish between the command and time specification, for instance by using a different name for the commands (e.g., ANYLABEL or ALLLABEL). At the moment we have not included this change into the text because 'ALL' and 'ANY' as commands are shorter.

29. p1912, L21: Don't you need to have at least 3 timesteps to ensure that a criterion applies for a minimum of 12 h (i.e. timesteps at 0, 6 and 12 h)?

The reviewer is correct. Strictly, a criterion could become valid, e.g., at time 6 h and remains so until time 12 h, after which the criterion might no longer be valid. In LAGRANTO, two labels would be set because the criterion is fulfilled at exactly these two time steps, but the overall time span when the criterion applies is only 6 h. We replaced 12 h with 6 h.

30. p1912: In the code ‘GT:LABEL(NONZERO):2:ALL’ how does LAGRANTO know which label is being tested given multiple labels could be defined?

This is indeed not clear. At the moment LAGRANTO does not allow the label to be specified for the comparison. If this turns out to be too restricting, a more refined command will be included in a future extension of LAGRANTO.

31. p1912, L23: ‘loose’ -> ‘lose’

done

32. p1913, L 7: ‘ist’ -> ‘is’

done

33. p1913, L14: change to ‘which has been’

done

34. p1916, L2: change to 'was chosen to be larger. . .'

done

35. p1916, L9: change to '. . . vertical coordinates. It is one of the main features of startf. . .'

done

36. p1917, L22: need to define PBL here (currently not defined until p1921).

Replaced with 'boundary layer height'

37. p1918, L10: 'very' -> 'many'

'very' is removed

38. p1919, L20: change to 'help predict..'

done

39. p1921, L12: $DPBL = P - PBL$, thus if a trajectory has had contact with the boundary layer its pressure must have exceeded that of the PBL and so I think DPBL should be positive (rather than negative as stated).

Thanks! Yes, DPBL becomes positive at contact with the PBL

40. p1923, L4: 'version' -> 'versions'

done

41. p1923, L14: what is meant by 'geographic coordinates'? For the MetUM at least the non-rotated coordinates are normally referred to as equatorial coordinates.

We replaced 'geographic' with 'equatorial' throughout the manuscript.

42. p1923, L25: 'list' -> 'lists', also consider using a comma after 'file'

done

43. p1925, L26: How can you partly need python as a software tool? Do you mean that you need python for some bits of LAGRANTO but other bits work without it?

Exactly! We changed the sentence to make it more clearly: "In addition to Fortran, several other software tools are needed, in particular Unix csh and Perl. Furthermore, for the visualization tool (see section 5.3) Python is required."

44. p1926, L6: 'since almost 20 years' -> 'for almost 20 years'

done

45. table 1: the last sentence in the caption doesn't make sense and has a spelling error. This sentence could be changed to match the equivalent sentence in the caption of table 2.

done

46. table 2: The use of bold is not consistent here e.g. the first example is for PV greater than 2PVU at any time and the second for PV greater than 2 at all times and yet different bits of the criterion are written in bold in the first column for these examples. I suggest removing the selective use of bold font in this table.

Done; we follow the reviewers suggestion and do not use highlighting with bold font in this table

47. fig 2 caption: 'allows studying of' -> 'allows study of'

done

48. fig 3: why is there a colon after the equals sign in the figure? Also, the use of superscripts * and ** for the different iterations of the forward steps is inconsistent with the text where subscripts (1) and (2) are used.

We have redrawn Fig. 3 and it should now be consistent with the text.

49. fig 4: 'starting position' -> 'starting positions' in caption

done

50. fig 5: should strictly note that the orography is in 'm' and also note that this field is shown in panel b as well as panel a

done; the unit is now mentioned in the figure caption, for both panels.

51. fig 6: please add units of both pressure and density to the caption.

The units are now added to the caption. To clarify the meaning of the density, we added the following sentence to the caption: "In total 1460 backward trajectories are included and then the 6-hourly trajectory positions are gridded onto a 1° x 1° latitude-longitude grid. The values correspond to the total counts per grid cells."