Reply to anonymous referee #2 (19/06/2015)

Interactive comment on "Sea surface temperature and torrential rains in the Valencia region: modelling the role of recharge areas" by F. Pastor et al. Anonymous Referee #2 (Received and published 14 June 2015)

I agree, in general lines, in the description and valuation made by Referee #1, and also in many details. In particular, I think the paper contains potentially significant contribution, but it needs MAJOR changes before publishing. I do not know what the editor will decide, but I have supposed that the authors will be as responsible to the Referee #1 requirements as they announce they will be in a new version of the paper. In my understanding, even so some changes could not be enough and I even suggest a few new details.

As "Referee #1" says, "The present paper describes three events of heavy rain in Valencia region, considering simulations performed with RAMS. Also, some sensitivity experiments are performed by changing the SST in some specific regions along the parcel trajectory ending in the precipitation area. In this way, the Mediterranean sub-regions that could have affected more deeply the precipitation amount and distribution are identified.

This new strategy to perturb the SST field is able to determine the regions that may have played a key role in the development of the torrential rain and then to investigate just the effect of that specific area in the model results. This approach is very interesting and could be applied also to other region in the Mediterranean basin".

However, major and minor aspects have to be reviewed before publishing. I the next, I will insist on some of these points and I also introduce some additional aspects, but I will not repeat all what Referee #1 said and the authors answered in a clearly satisfactory line.

We would like to thank the reviewer for a fast and detailed review of our manuscript and also, as in the case of reviewer 1, for his/her positive appreciation of the potentially significant contribution of the paper. We will also consider reviewer comments and indications to, hopefully, improve paper's next version that we hope could be finally accepted for publication.

We want to specially thank reviewer 2 for reading and considering our response to reviewer 1 comments and his/her positive appreciation.

MAJOR POINTS:

Regarding MAJOR POINTS, I have to insist in questions regarding SST climatologies and SST initial values. About climatology, perhaps after carefully reading the first author's thesis (Pastor, 2012) it becomes clearer, but I think the text of the present paper has to be clear enough by itself, in this sense. Which is the base for doing the clustering process? Which are the n-dimensional elements that are used, are they SST values in every grid point? Are they gridpoint daily values, along a unique period, 1982-2009? Are they grid-point monthly average values along the unique period? Are the data seasonally stratified (by seasons, by months), before doing the clustering process (that is, is there a clustering process for every season or for every month or an only one process? In case of a unique clustering process with grid-point monthly average data, how to define winter/summer, seasonal or monthly cluster assignations? In Fig. 1, it is quite surprising the almost exact similarity (with regard to shape) between the seasonal SST isotherms and the “winter”, “summer”, “transition1” and “transition2” cluster limits.

We agree with the reviewer that, probably, more detailed information about SST monthly climatology used in the simulations is needed. The reason for this lack of information should be attributed to our interest, in this paper, to focus on the results of the numerical modelling rather than in the SST climatology. However, we will try to resolve the reviewer questions by including a short but more detailed explanation about SST climatology in the article.

The climatology was built by the first author in his doctoral thesis (Pastor 2012) with daily SST data obtained from NOAA/NASA Pathfinder data base (cited in the 2.1 section, first paragraph). These data consists in two daily values (nighttime and daytime) for any grid point across the whole data period 1982-2009. Nighttime values have been used to build a monthly climatology; if nighttime data were not available then daytime were used. For building the monthly climatology, at least 75% of the possible monthly values were required on any grid point. If less data were available, then a simple interpolation technique was used to calculate monthly SST from the surrounding valid points.

Once monthly data were available in separate data files, a clustering process was run for each month in order to "objectively" look for areal division of the Mediterranean. After running clustering process for any month in the 1982-2009 series, we studied the whole series of cluster maps and found the presence of two main distribution patterns for SST in winter and summer with transitional periods between them, also seen in a time analysis of the mean SST for each zone. The maps in figure 1 are "prototypical" examples of such regimes.

Actually, some isotherms coincide with cluster borders in figure 1. This is not surprising for the authors as we have more information about SST and clustering than is shown in this paper. The maps in figure 1 show distant areas grouped in the same cluster, as can be the Alboran Sea, Gulf of Lion on spring, summer and autumn but not in summer when general SST distribution pattern is different. Also, Alboran sea is in the same cluster than the Adriatic sea in autumn but not in winter. Additionaly, maps for each monthly SST repeatedly show "almost the same" areas, with slightly different shape/extension, but also with slightly different values, i.e. each january show similar clustering structure although slightly different SST values appear from year to year. Indeed, not any month always shows the same number of clusters.

In the next future we are waiting for the release of a new version (5.2) of the Pathfinder SST data base, in its monthly values, to rebuild the climatology and clustering for a longer period.

For addressing these questions we have changed part of 2.1 section (page 1362, line 14)

"A monthly climatology for the period January 1982 to December 2009 to study SST in the Mediterranean was used Pastor (2012). Additionally, clustering techniques were used to study SST spatial distribution patterns across the whole study period for monthly values and anomalies."

to

"A monthly climatology for the period January 1982 to December 2009 was built in Pastor (2012) to study SST in the Mediterranean. Mean monthly values were built from daily data in every grid point covering the Mediterranean, with the restriction of having at least 75% of valid daily values, preferably nighttime values but using daytime ones if they were not available. Additionally, clustering techniques were used to study SST spatial distribution patterns across the whole study period for monthly values and anomalies. "

About the SST initial field that is used in the control run, for every case, in the initial text it is no clear but it continuous not being very clear for me after the response of the authors to Referee #1. From the last figure that is included in this response, it seems that the initial SST values that have been used are the monthly average values of the corresponding actual month or of the month before (Oct-2007 for the Oct-2007 case, Oct-2000 for the Oct-2000 case and Aug-1989 for the Sep-1989 case). Why the precedent month in the 1989 case? Why do not use actual initial daily SST? Monthly averages can sensible differ from daily values. It seems that an ideal way to treat with air-sea exchange question is the use of actual sea data, even with changes along the integration, through variable boundary conditions or by using and air-sea exchange complementary model. Average monthly values seem to be poor data. The other point is how and why to assign “summer”, “winter” and “summer to winter transition” models of a clustering distribution in order to introduce SST changes in the sensitivity experiments.

From our knowledge about mediterranean SST and from the results from the first author thesis, our main purpose in this paper was to study the role of SST from different areas in the Mediterranean on the modeling results of heavy rains in the Valencia region and, hopefully in the future, in other regions. It was not our intention to specifically address the study of an individual rain event but look for events that could be related with some of the SST distribution patterns we were interested in. Obviously, for an exhaustive study of individual rain events it is preferable to use actual and recent SST data the closest possible to the rain event but we must insist this was not our intention.

From the analysis of the complete SST data series, maps and clustering results it is possible to determine the repetition of patterns at certain times of the year. This analysis permitted us to assign the different monthly data to winter, summer or transition patterns. After SST classification, we looked for rain events that took place in months when any of the regimes were present and chose the three events that have finally been analyzed.

Regarding the September 1989 event, we used SST from the previous month because rain occurred from days 5 to 7 and SST spatial distribution resemble more to a summer (august) distribution. In the case of October 2007 rains took place in days 11 and 12, we used October 2000 SST because it showed a clear winter distribution while September was a transitional one.

A question also mentioned by Referee #1, about the back trajectories, is also a major point and I wish to insist on it. It is no clear if the back trajectories, both from NCEP analyses or from RAMS runs, are 2D or 3D trajectories. In the first case, these are not realistic trajectories: they are a conceptual simplification. Real trajectories are usually 3D, with significant changes in level along the trajectory in many cases. This means that 3D trajectories have to be considered, but even when considering low level final (arriving) level the initial (departing) level can be quite high and then a direct heat and water exchange with the sea is not possible. There is no problem in modifying SST in some areas (defined by a previous clustering or by another way), but to consider that the areas that have to be considered for it are the areas under a black trajectory can not have a robust foundation, at least for distant segments of back trajectories, running at a relatively high level. Of course, at short distances the 2D and 3D back trajectories can be vertically close each other and the problem vanishes. The effect of SST changes on heavy precipitation is then logically more important for marine areas closer to the heavy precipitation zone.

Although not shown in the final figures, trajectories from reanalysis data are 3d trajectories computed using model vertical velocity. Please, find attached figures at the end of the supplement which show vertical movement of the air parcel for different final heights.

As reanalysis trajectories showed weak vertical movement, we choose the lowest level reanalysis trajectory to compare with RAMS trajectory for the lowest model level.

At first we thought 48 hour reanalysis trajectories were enough for representing the air mass marine path, now we have extended to 72 hours while RAMS trajectories run for the start of the simulation until the trajectory ending time.

Measuring the effect of SST modification needed a comparison between the observation and the simulations, not only the control simulations. This point was also mentioned by Referee #1 and it has been positively responded by the authors trough the introduction of observed precipitation, for each case. I would suggest to also adding some numerical indicators. To be strict, the most convenient way to measure effect of changing in factor on the precipitation fields is though a complex way based on shape recognition (SAL or some others methods), but it could be enough to do and indication based on maximum and total precipitation in a delimited area.

We agree with the reviewer that there are methods for objectively evaluating model results accuracy in terms of precipitation. At this time, we think that the inclusion of observed precipitation maps and citation of previous work in which RAMS model accuracy was evaluated for October 2007 event properly address this issue.

With regard to possible forecasting interpretation of the results, a reduction of SST from values of around 20ºC to 10ºC can give a qualitative idea, but it is far from realistic changes. Perhaps some intermediate values could have to be used to analyse the impact of SST on close marine areas to heavy precipitation on land. But I understand this would be a too demanding change and that is very difficult for the authors to assume this utopian suggestion.

Some authors deal with SST effects on model results modifying data by adding/subtracting a fixed value to the whole domain; this could be considered an unrealistic change to accurately represent SST but a useful technique for "idealized" studies. Other authors use different data sources to look for SST effect on model results; this could be a more realistic approach. In our case, we chose the "idealized case" approach.

With the drastic reduction of SST values to 10ºC we tried to completely remove air-sea exchanges over modified areas so we could evaluate, by looking at differences in model results, the contribution of those areas to the rain event. With a most extensive study, our aim is to identify areas that most contribute to torrential rain in our region.

Probably, the use of intermediate SST values would permit to find areal thresholds that permit the onset of air-sea heat or moisture exchanges. This is an interesting point that should be explored in future work, with probably significant results on forecasting of torrential rains.

Going to some additional MINOR points, first (page 1359, lines 1-3), the idea of a particular Mediterranean meteorology as a consequence of a singular geography, characterised by a close and relatively isolated sea, surrounded by elevated terrain, is clearly prior to Millán et al. (2005).

Of course, Mediterranean meteorology science has a long track before this citation. Millan paper compiles the work of different research projects, some of them with participation of the authors, to give a global view of the Mediterranean system. Research in this paper started from/followed some of the research cited in Millan paper.

Nevertheless, we have added a reference to a paper by Jansà et al (2001) in which the importance of Mediterranean orography (Spanish-Pyrenean orography in this case) in generating/intensifying a cyclone is shown. Of course, we are open to accept suggestions of relevant papers that could be cited about Mediterranean meteorology.

In page 1359, lines 5 to 12, some kind of conceptual mixing seems to appear. Perhaps it is convenient to clarify that heavy/torrential rain and cyclone/cyclogenesis are independent concepts, although in many cases cyclones are acting factors in the organisation and onset of heavy rain (see, for instance, Jansa et al., 2001, Meteorol. Appl., 8, 43-56, Jansa et al., 2014, Nat. Hazards Earth Syst. Sci., 14, 1965–1984, and references in both). Possibly analogous confusion (or confused expression) appears before, in page 1359, by line 15 and surroundings. Note that the title of the first author's thesis (Pastor, 2012), also could indicate some kind of equivalence between two different concepts, heavy rain and intense cyclogenesis. A relationship (or simultaneity) can exist, but between different phenomena.

We don't agree with the reviewer appreciation of conceptual mixing in the paper introduction. We agree that heavy rains in the Mediterranean are not always linked to cyclogenesis and it was not our intention in this paper to claim the opposite. However we have added a reference to the paper by Jansà et al, 2001, in which conclusions states:

"... the frequency of simultaneity between heavy rain and a cyclone center in the vicinity decreases to 80%. For some places (Valencia and the Balearic Islands, in Spain), this frequency increases to 99%. When only the heaviest rain events are taken into account, the percentage of simultaneity between heavy rain and a cyclone center in the vicinity reaches to 100% for Valencia and the Balearics and 97% fot some French areas and Catalonia (Spain)."

Page 1362, line 15, the SST monthly climatologies, were they used or where they developed by Pastor (2012)?

As previously explained, monthly values were developed by Pastor (2012)

Page 1364, lines 15 and following. It seems not, but perhaps it is convenient to indicate that SST is not included within the initial and boundary conditions package.

The following text will be added at the end of the cited paragraph to clarify this point:

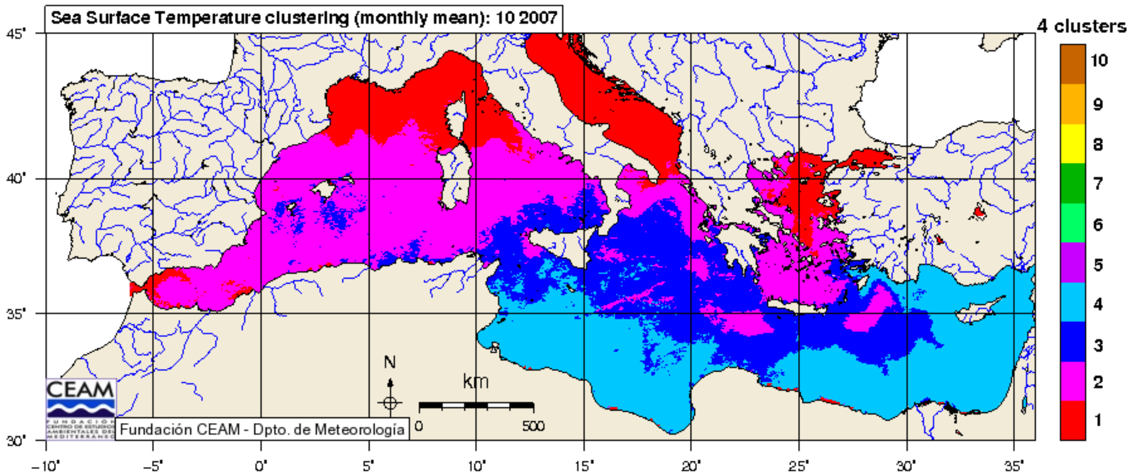
"SST intial data for the simulation was obtained for the model domain from the NASA/NOAA Pathfinder data bases."

In Fig. 3, RAMS simulated back trajectories are much longer than the analysed ones, why?

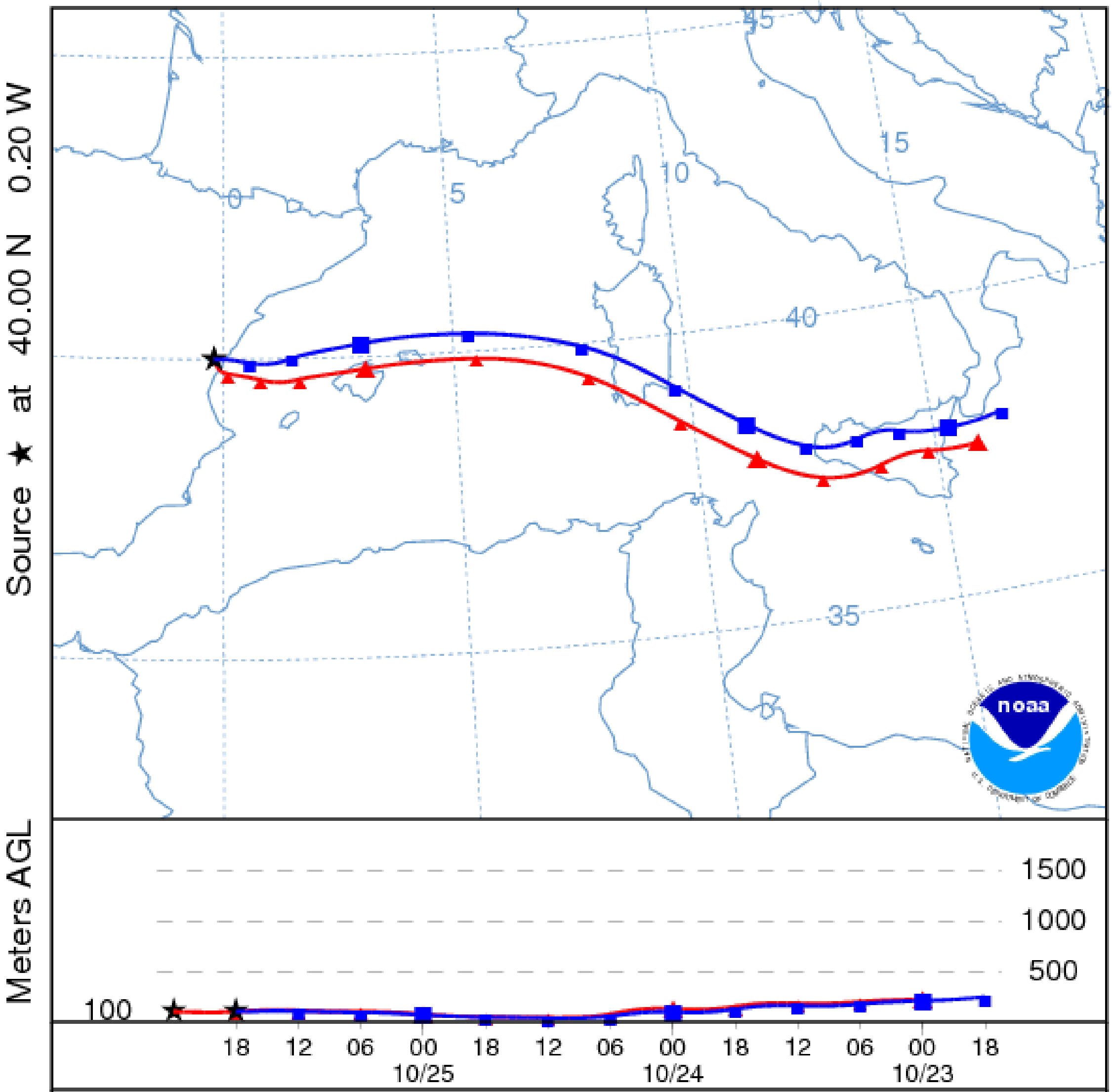
As explained before we assumed that 48 hour reanalysis trajectories were good enough to show the air mass marine path. We have extended trajectories to 72 hours while RAMS trajectories run for the start of the simulation until the trajectory ending time.

In Fig. 7, RAMS simulated back trajectories are not only longer, but also different to the analysed ones.

In this event, the reanalysis trajectories run to the north of RAMS ones between Sardinia and the Balearics. Monthly mean SST clustering shows both trajectory groups run over the same cluster, so we think the difference in this part of the trajectories does not make a significant difference in the model results.



NOAA HYSPLIT MODEL
Backward trajectories ending at 0000 UTC 26 Oct 00
CDC1 Meteorological Data



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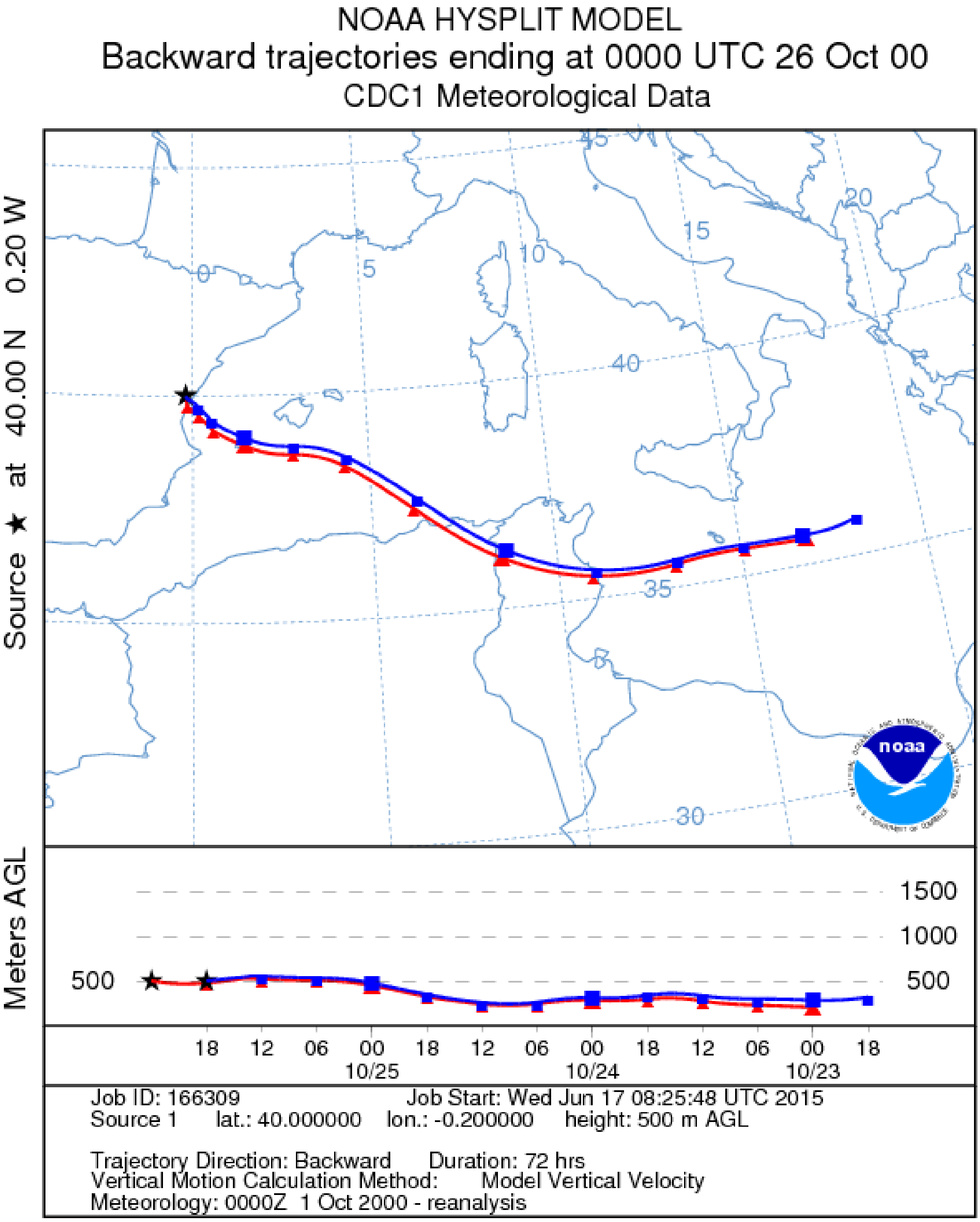
Vertical Motion Calculation Method: Model Vertical Velocity
Meteorology: 0000Z 1 Oct 2000 - reanalysis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Backward trajectories ending at 0000 UTC 26 Oct 00
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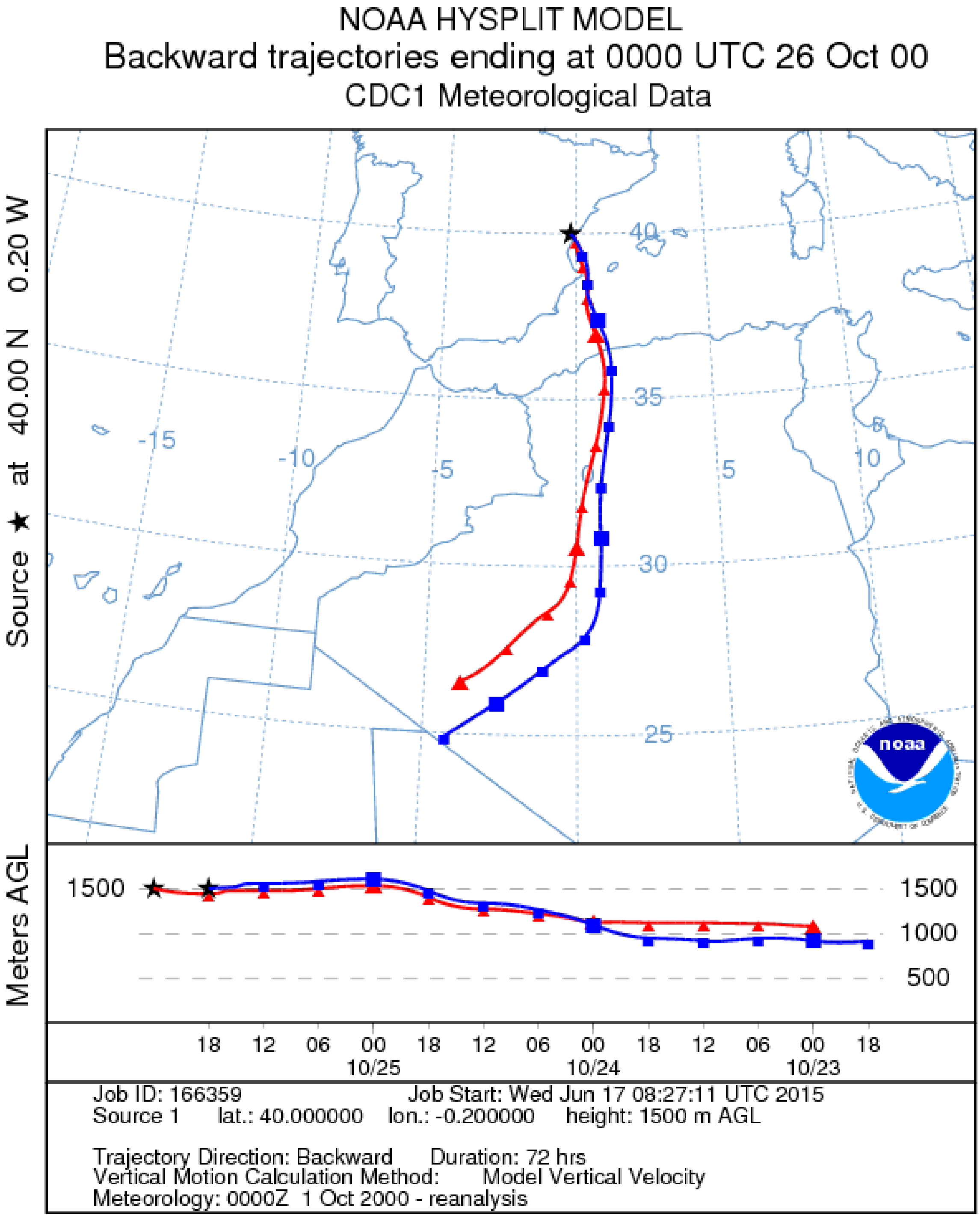
Meteorology: 0000Z 1 Oct 2000 - reanalysis


NOAA HYSPLIT MODEL
Backward trajectories ending at 0000 UTC 26 Oct 00
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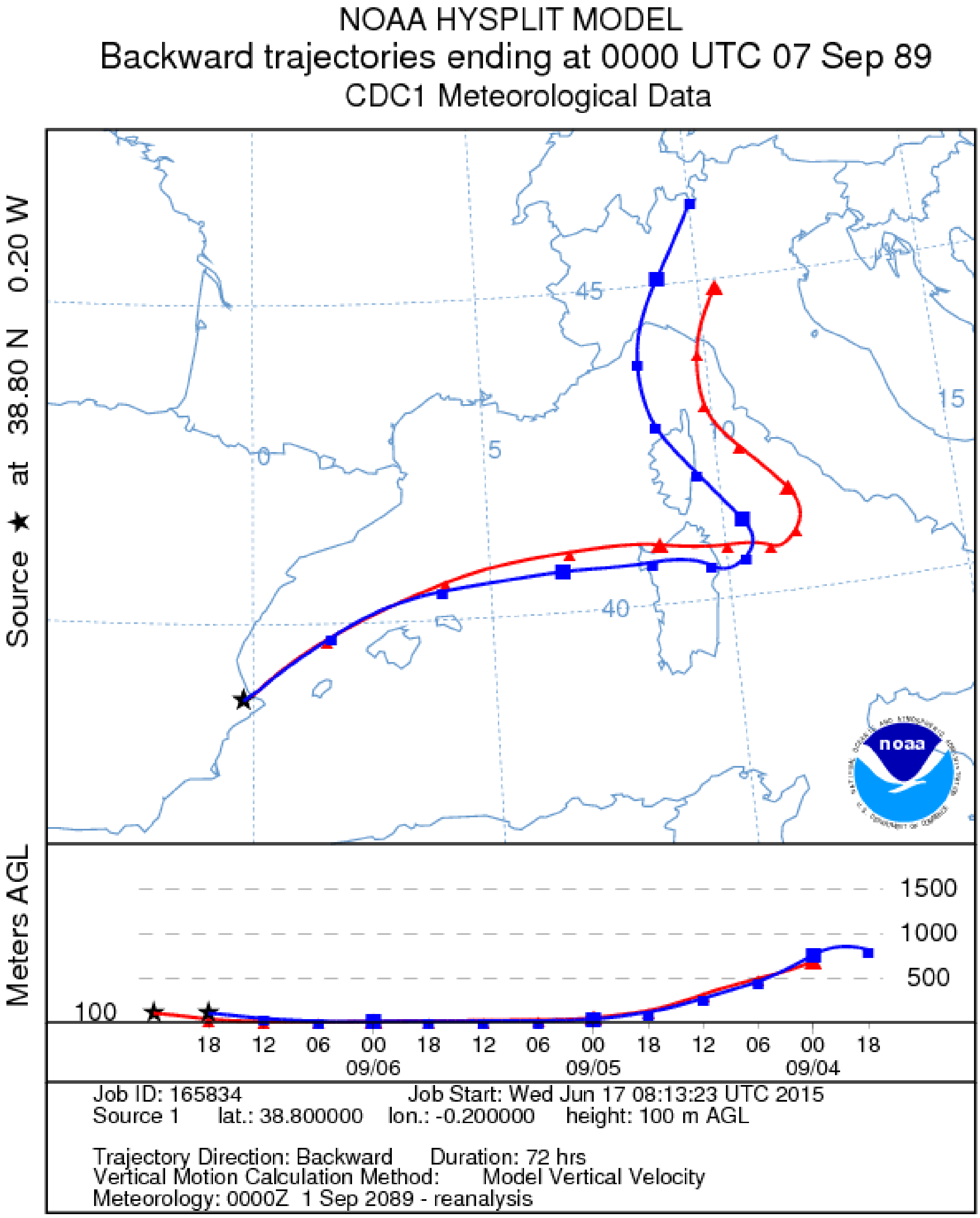
Meteorology: 0000Z 1 Oct 2000 - reanalysis


NOAA HYSPLIT MODEL
Backward trajectories ending at 0000 UTC 07 Sep 89
CDC1 Meteorological Data
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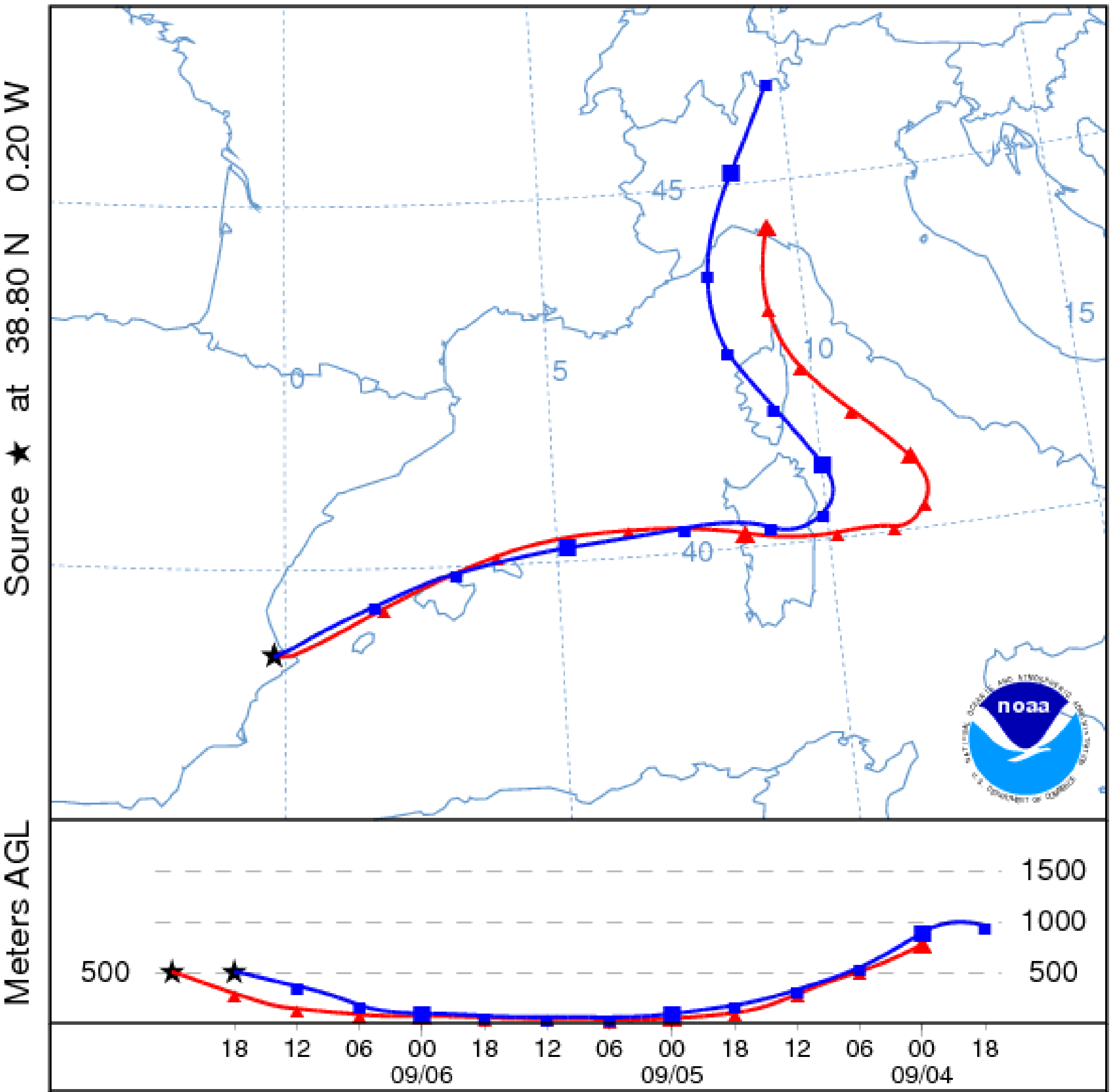
Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Meteorology: 0000Z 1 Sep 2089 - reanalysis

NOAA HYSPLIT MODEL
Backward trajectories ending at 0000 UTC 07 Sep 89
CDC1 Meteorological Data



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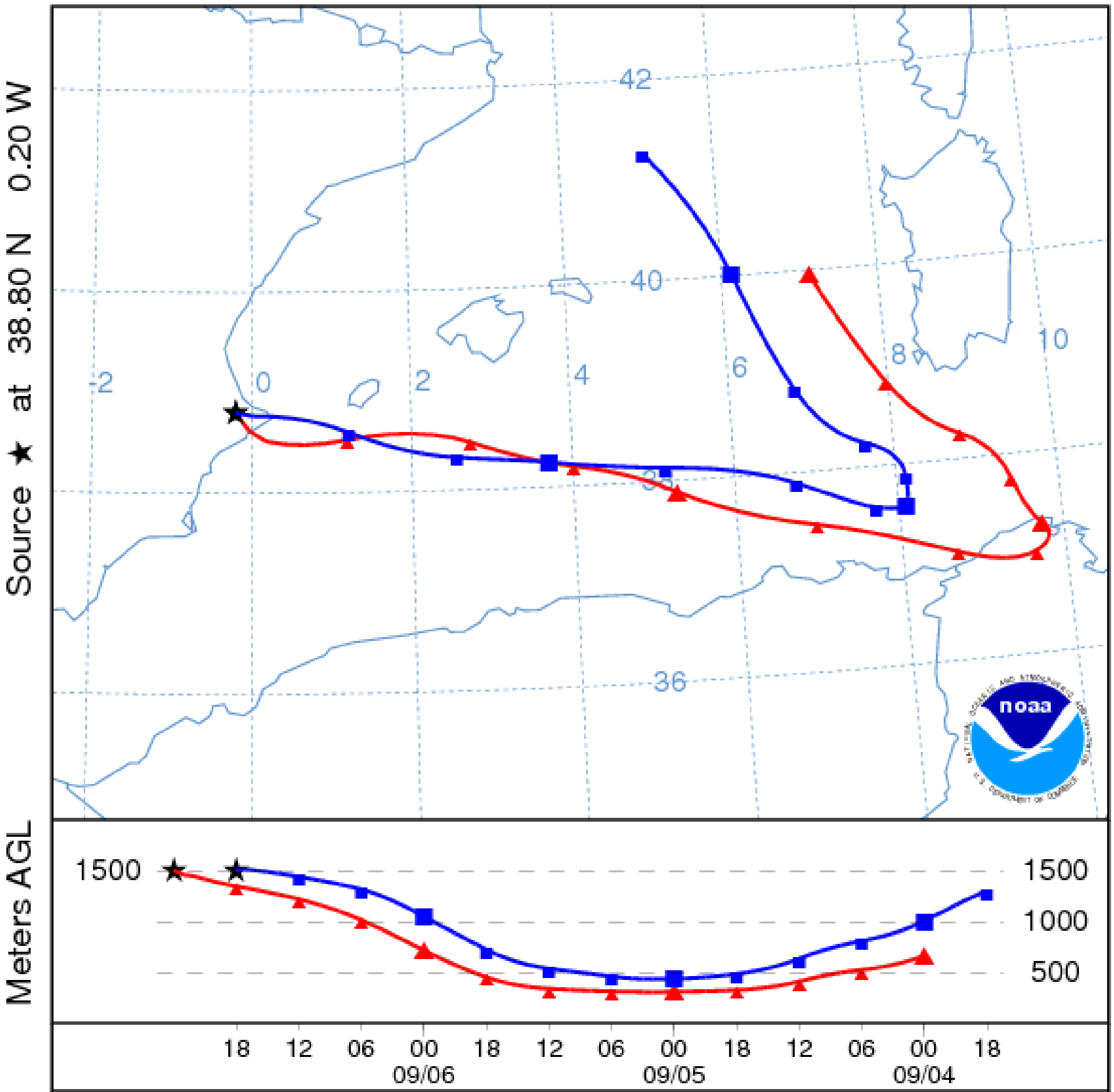
Meteorology: 0000Z 1 Sep 2089 - reanalysis

NOAA HYSPLIT MODEL
Backward trajectories ending at 0000 UTC 07 Sep 89
CDC1 Meteorological Data



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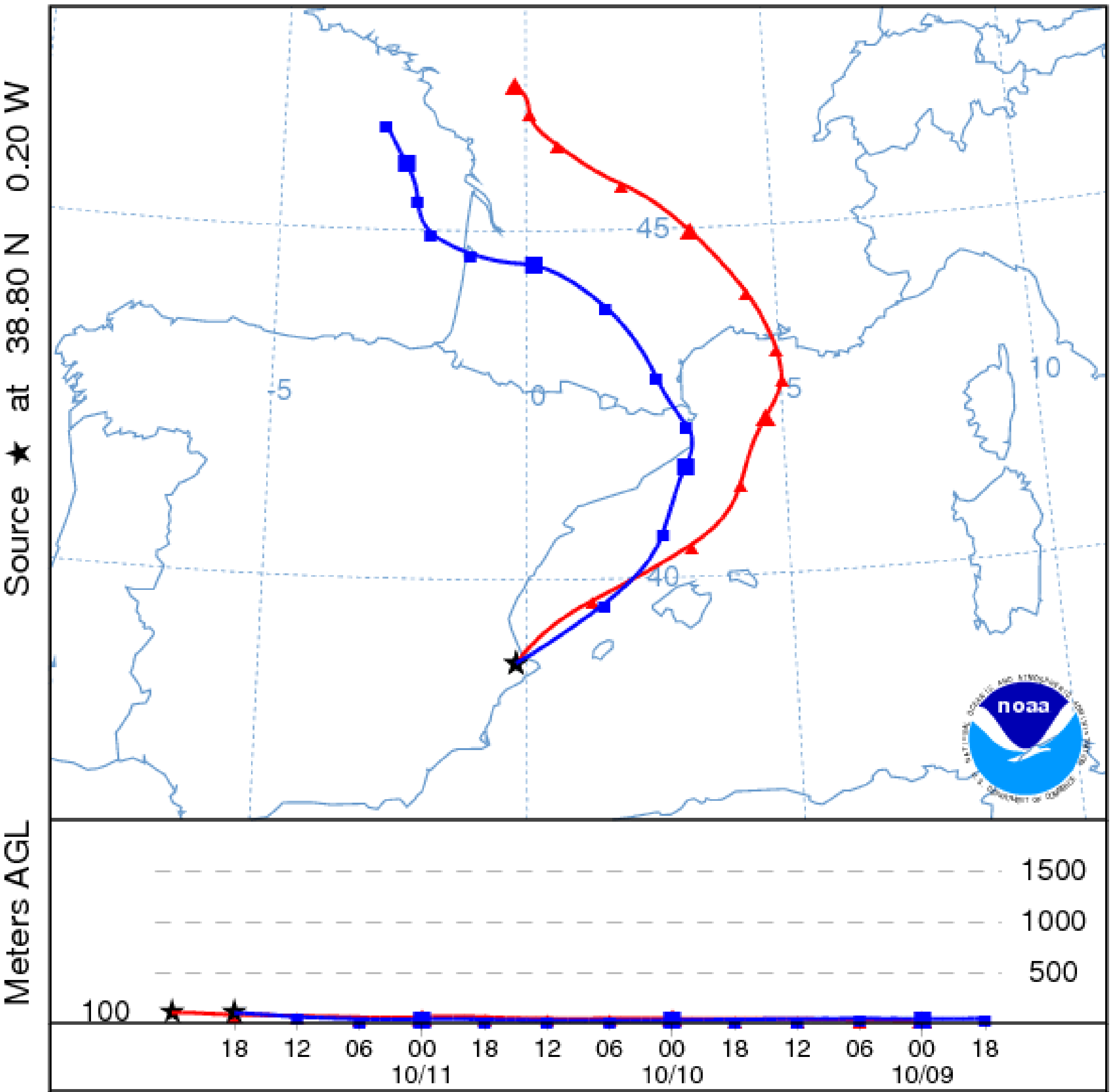
Meteorology: 0000Z 1 Sep 2089 - reanalysis

NOAA HYSPLIT MODEL
Backward trajectories ending at 0000 UTC 12 Oct 07
CDC1 Meteorological Data



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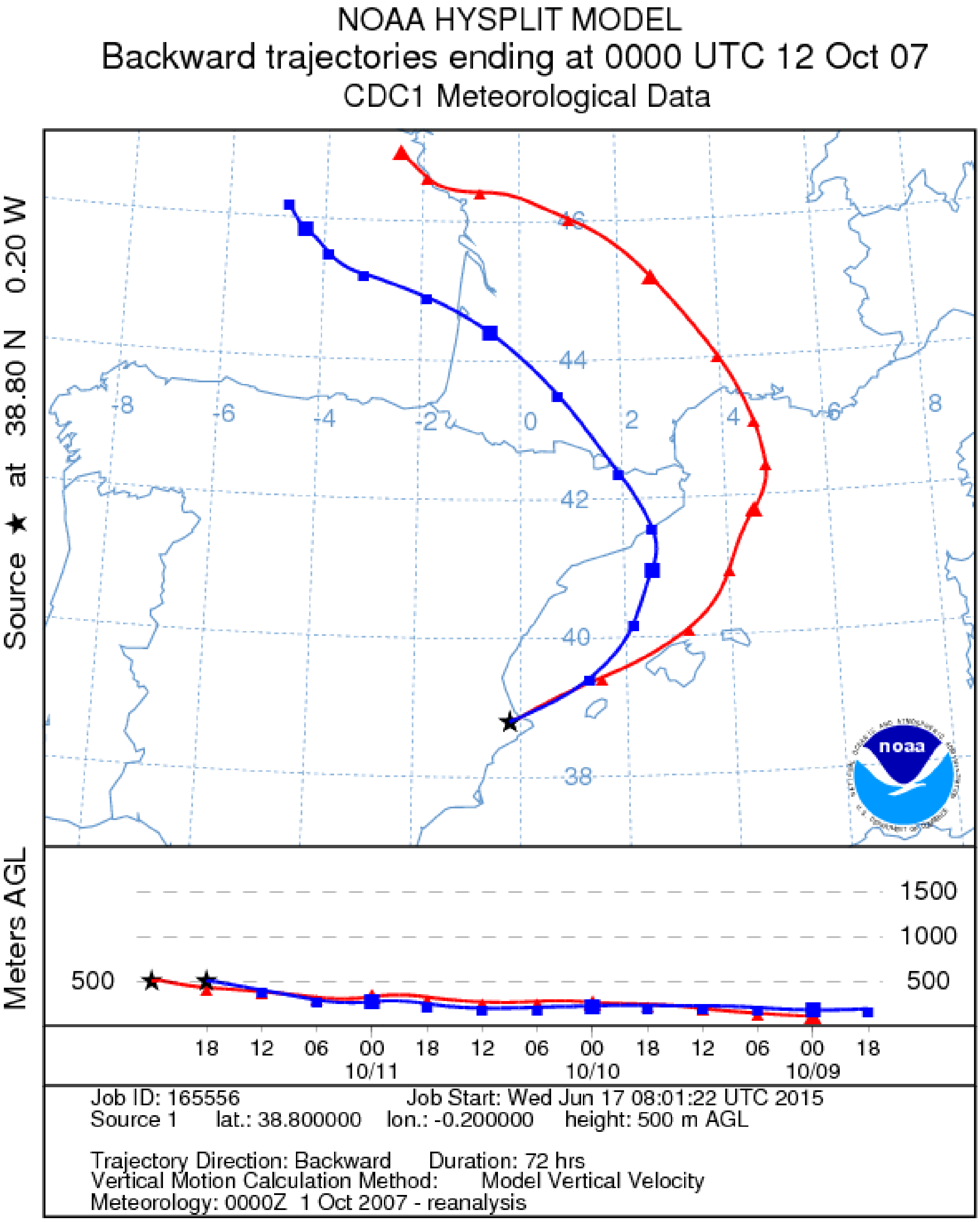
Meteorology: 0000Z 1 Oct 2007 - reanalysis


NOAA HYSPLIT MODEL
Backward trajectories ending at 0000 UTC 12 Oct 07
CDC1 Meteorological Data
Source ★ at 38.80 N 0.20 W
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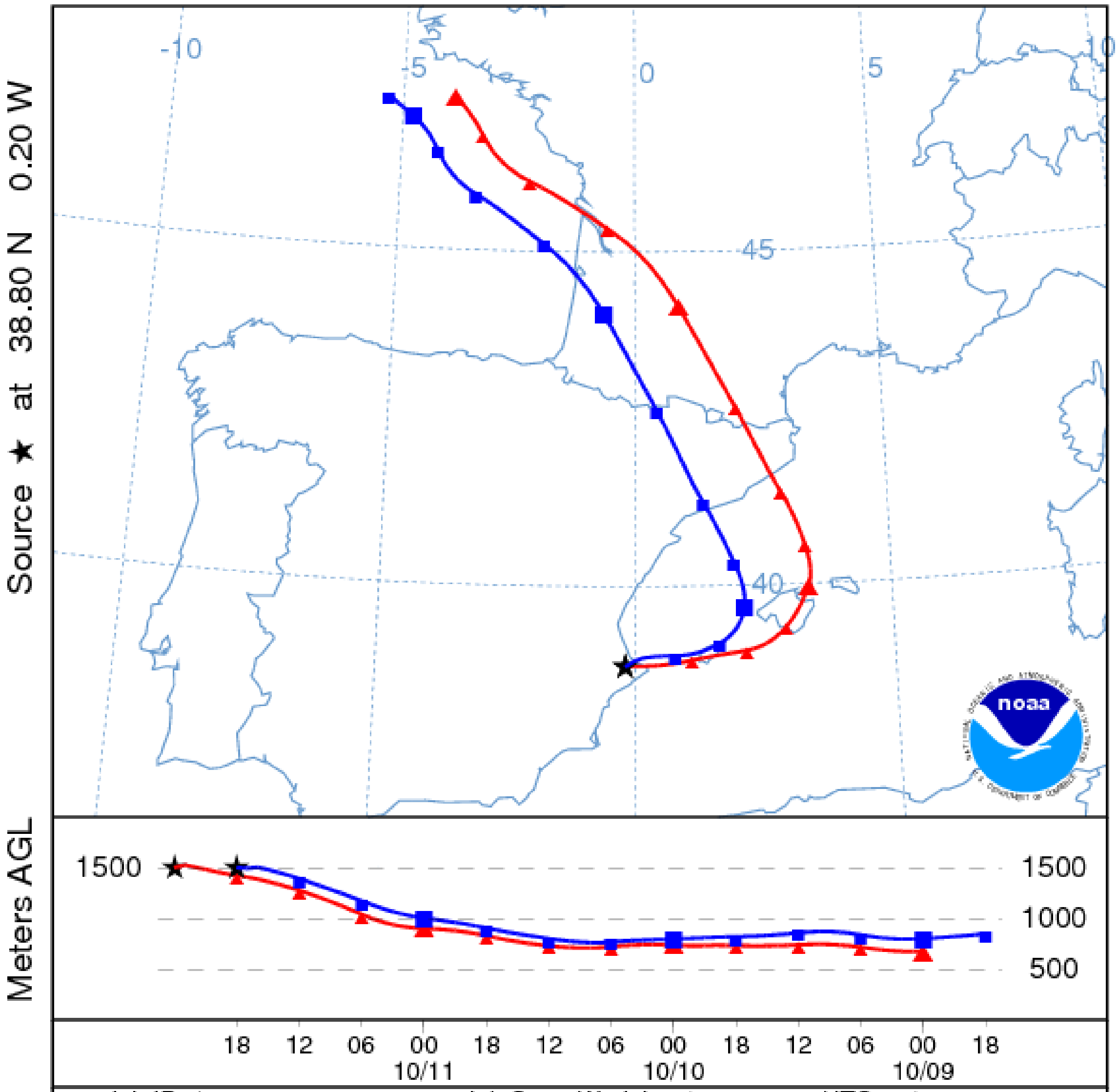
Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Meteorology: 0000Z 1 Oct 2007 - reanalysis

NOAA HYSPLIT MODEL
Backward trajectories ending at 0000 UTC 12 Oct 07
CDC1 Meteorological Data



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Trajectory Direction: Backward Duration: 72 hrs
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Meteorology: 0000Z 1 Oct 2007 - reanalysis