OZONE APPORTIONMENT USING THE OZONE PRECURSOR TAGGING METHODOLOGY (OPTM)

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Prepared by

Tom C. Myers and Sharon G. Douglas
Systems Applications International, Inc.
101 Lucas Valley Road, Suite 230
San Rafael, CA 94903

Introduction

The analysis of ozone model simulations has been used for many years to assist in developing emissions control strategies that effectively reduce ozone within ozone exceedance areas. Sensitivity simulations are often used to estimate which categories of emissions or which areas within a domain have the largest effect the ozone peak or on monitored ozone concentrations. In these sensitivity simulations, a category of emissions is removed, or zeroed out, in the model input files. The simulation is conducted with all other inputs the same as the baseline simulation. The change in ozone is then interpreted as the amount of ozone attributed to the particular emissions category.

Modelers have recognized some drawbacks to the sensitivity simulation methodology for estimating ozone contributions. First of all, a separate simulation must be set up and run for each category that is to be investigated. Second, since the response of the ozone chemistry may be quite non-linear for significant changes in the emissions, the estimated change in ozone may be valid for only the specific change in emissions that was simulated. That is, if the elimination of a category of emissions resulted in a 20 ppb change in ozone, it does not necessarily follow that elimination of half that amount of emissions would result in a 10 ppb change in ozone.

In order to augment the information available from sensitivity simulations, SAI has developed the Ozone Precursor Tagging Methodology (OPTM) that can provide estimates of various source categories to ozone levels. The estimates are made for the existing conditions within the simulation and do not require that the system be perturbed in order to make the estimate. In addition, estimates for several categories can be made in a single simulation.

Technical Formulation

Ozone exists in the atmosphere in a dynamic equilibrium with NO and NO2. NO2 is photolyzed by sunlight to form NO and a free oxygen atom that combines with an oxygen molecule to form ozone. The ozone and NO recombine rapidly recombine to reform the NO2 and oxygen molecules. Since it is the oxidized form of the molecules that contribute directly to the ozone present at a given time, a useful quantity to consider is

the amount of oxidant present, the sum of NO2 and ozone. While ozone may drop rapidly when fresh NO emissions are added to the system, the amount of oxidant varies more slowly. When the NO emissions are added, ozone is converted to NO2, but the sum of NO2 and ozone stays the same. The amount of oxidant present varies slowly, increasing due to the interaction of VOCs, NOx and sunlight, and decreasing through removal processes such as deposition and conversion to nitric acid. The OPTM system tracks the amount of oxidant (the sum of NO2 and ozone) formed from various source categories as a method of estimating the contributions to ozone.

In order to estimate the contributions to ozone, OPTM sets up several new tracer species in a simulation that are used to tag emissions or chemical products. The total emissions of VOC and NOx from the desired categories are tagged. For illustration, we will assume that there are two categories, with VOC-1 and NOX-1 and VOC-2 and NOX-2 corresponding to the two categories. In addition to these emissions tracers, oxidant tracers called OXN-1, OXV-1, OXN-2, and OXV-2 are added corresponding to the oxidant produced from NOx and VOC in each of the two categories.

All of the tracers are advected like normal species. They also undergo deposition, but a deposition velocity is not calculated for the tracers. Instead, the fractional change of oxidant (meaning NO2 + O3) is calculated due to the effects of deposition, and this same fractional change is applied to the oxidant tracers. Similarly, the VOC and NOX tracers are adjusted according to the change in the total VOC and NOX.

A crucial step in the OPTM system is the calculation of the change in oxidant during the chemistry step of the model. Prior to the chemistry step, total VOC, total NOX, and total oxidant are calculated. The chemistry step is then called as usual, using the standard CB-V species (NO, NO2, O3, PAR, OLE, TOL, etc.). After the chemistry step, new values of total VOC, NOX, and oxidant are calculated so that the change in VOC, NOX, and oxidant can be calculated (call these ΔVOC, ΔNOX, and ΔOX).

The change in OXN-1 is ΔOX*NOX-1/(NOX-1 + NOX-2), where the NOX-1 and NOX-2 values are at the beginning of the time step. Similarly, the change in OXV-1 is ΔOX*VOC-1/(VOC-1 + VOC-2). Corresponding calculations are made for the –2 tracers.

The changes in the VOC and NOX tracers are also calculated. The change in VOC-1 is ΔVOC/VOC * VOC-1 and the change in NOX-1 is ΔNOX/NOX*NOX-1, with corresponding calculations for the –2 tracers.

The simulation proceeds as usual from this point.

After completion of the simulation, the ozone attributed to a source category is calculated using both the calculated ozone concentration and the oxidant tracer concentrations, as follows:

Ozone attributed to category 1 NOx = O3*OXN-1/(OXN-1 + OXN-2)
Ozone attributed to category 2 NOx = O3*OXN-2/(OXN-1 + OXN-2)
Ozone attributed to category 1 VOC = O3*OXV-1/(OXV-1 + OXV-2)
Ozone attributed to category 2 VOC = O3*OXV-2/(OXV-1 + OXV-2)

Example Results Using OPTM

In the following example, specific areas within the modeling domain were defined as separate tags. One tag was the anthropogenic emissions from Calcsieu Parrish in Louisiana. Another tag was anthropogenic emissions from several counties in the Houston area. A third tag tracked anthropogenic emissions from the Beaumont-Port Arthur area. Finally, another tag was used to track all biogenic emissions and the remainder of the anthropogenic emissions in the domain.

The results of the simulation can be displayed in a number of different ways. Figure 1 shows the results displayed for specific locations within the domain, with the contributions to afternoon ozone broken down into the various contributors.

On the other hand, spatial maps of the contribution to ozone can be prepared for each of the tagged emissions areas. Examples of these maps are shown in Figure 2 for the VOC tags and in Figure 3 for the NOx tags.

This example shows the method used for estimating contributions from areas within the modeling domain. However, the method can also be used for categories of emissions: mobile vs. non-mobile, elevated vs. low-level, etc. There is no explicit limit to the number of VOC or NOx tags that can be set up within a single simulation.

Figure 1. Ozone apportioned by NOx/VOC, 16:00 – 17:00, August 19, 1999, Vinton (top) and Westlake (bottom) sites.

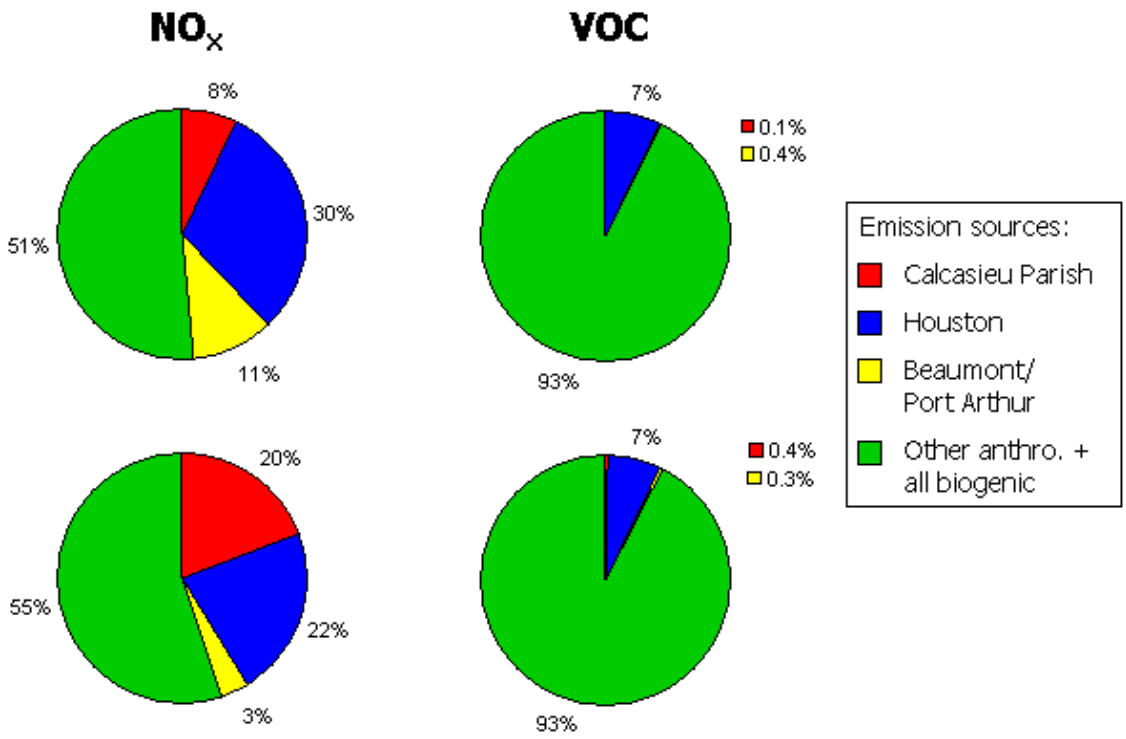


Figure 2. Ozone (ppb) apportioned by VOC, 16:00 – 17:00, August 19, 1999

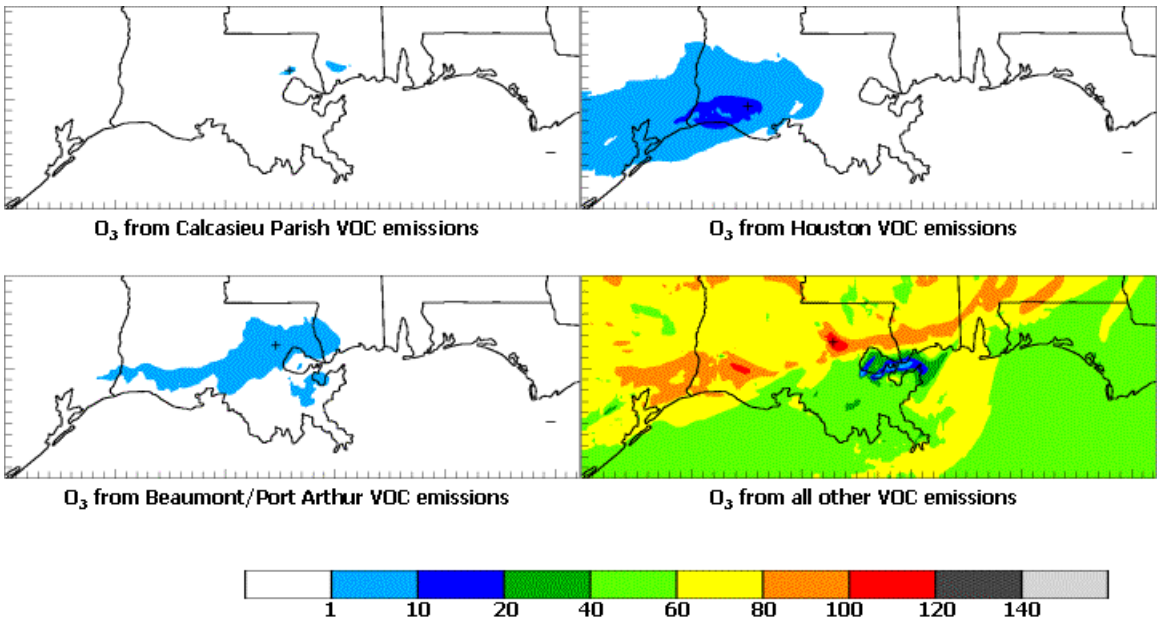
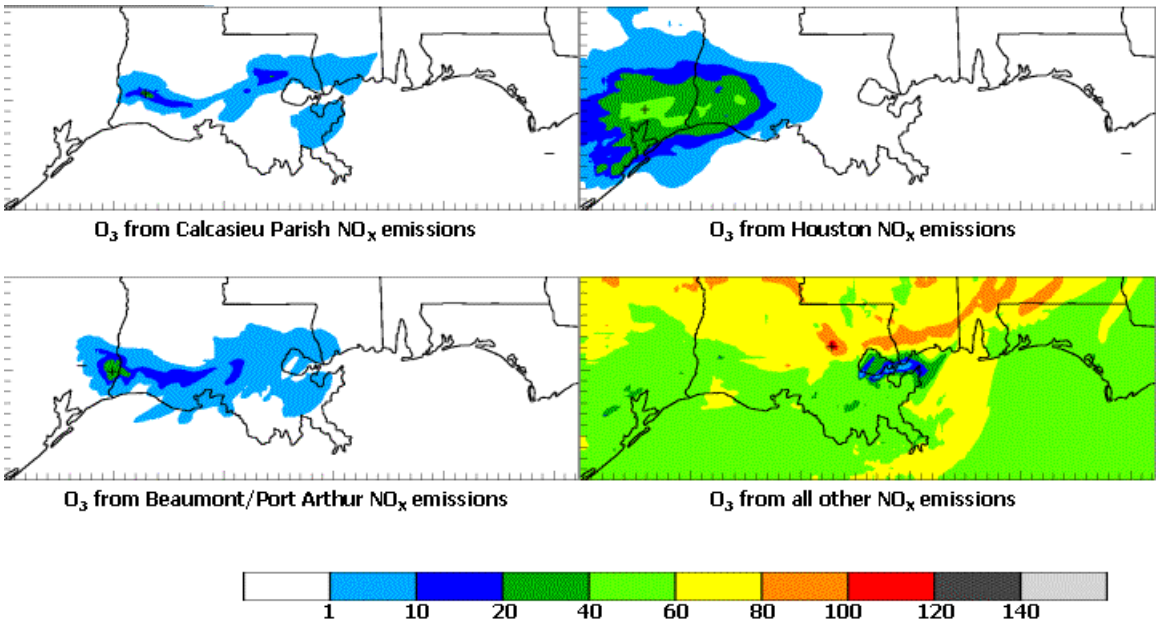


Figure 3. Ozone (ppb) apportioned by NOx, 16:00 – 17:00, August 19, 1999



DeSoto County Population and Growth

According to the 2000 Census, the population of DeSoto County is 107, 199, which is an increase of 39,289 people from the 1990 Census. The population of Shelby County, TN, is 897,472 which is an increase of 71,142 people from the 1990 Census. While the percentage growth in DeSoto County is higher than Shelby County, the numerical growth is higher in Shelby County.

Based upon the information from the Center for Policy Research and Planning, Mississippi Institutions for Higher Learning, which are the official state demographers, the DeSoto County population will be 121, 000 for 2007 and 135,000 for 2012. The Source of these projections is the Center for Policy Research and Planning, Mississippi Institution of Higher Learning, March 2002. (http://www.ihl.state.ms.us/urc/planning/pop0601.pdf)

DeSoto County Commuter Traffic

A question was raised asking if the zeroing out of DeSoto County also removed the contribution of DeSoto County commuters from the Shelby County inventory. It did not. However, according to 2000 US Census data, the population of DeSoto County is approximately 107,000 with 28,000 commuting to Shelby county compared to Shelby County's population of approximately 897,000 with 403,000 commuters. The amount of contribution from DeSoto County commuters would be relatively insignificant.

In addition, all anthropogenic emissions in DeSoto County were zeroed for the modeling. This included all traffic along Highway 61, Interstate 55, and Highway 78. Most of the traffic on these roadways is pass through traffic that does not begin or end in DeSoto County. The emissions from this traffic more than compensates for any in Shelby County that was not removed.

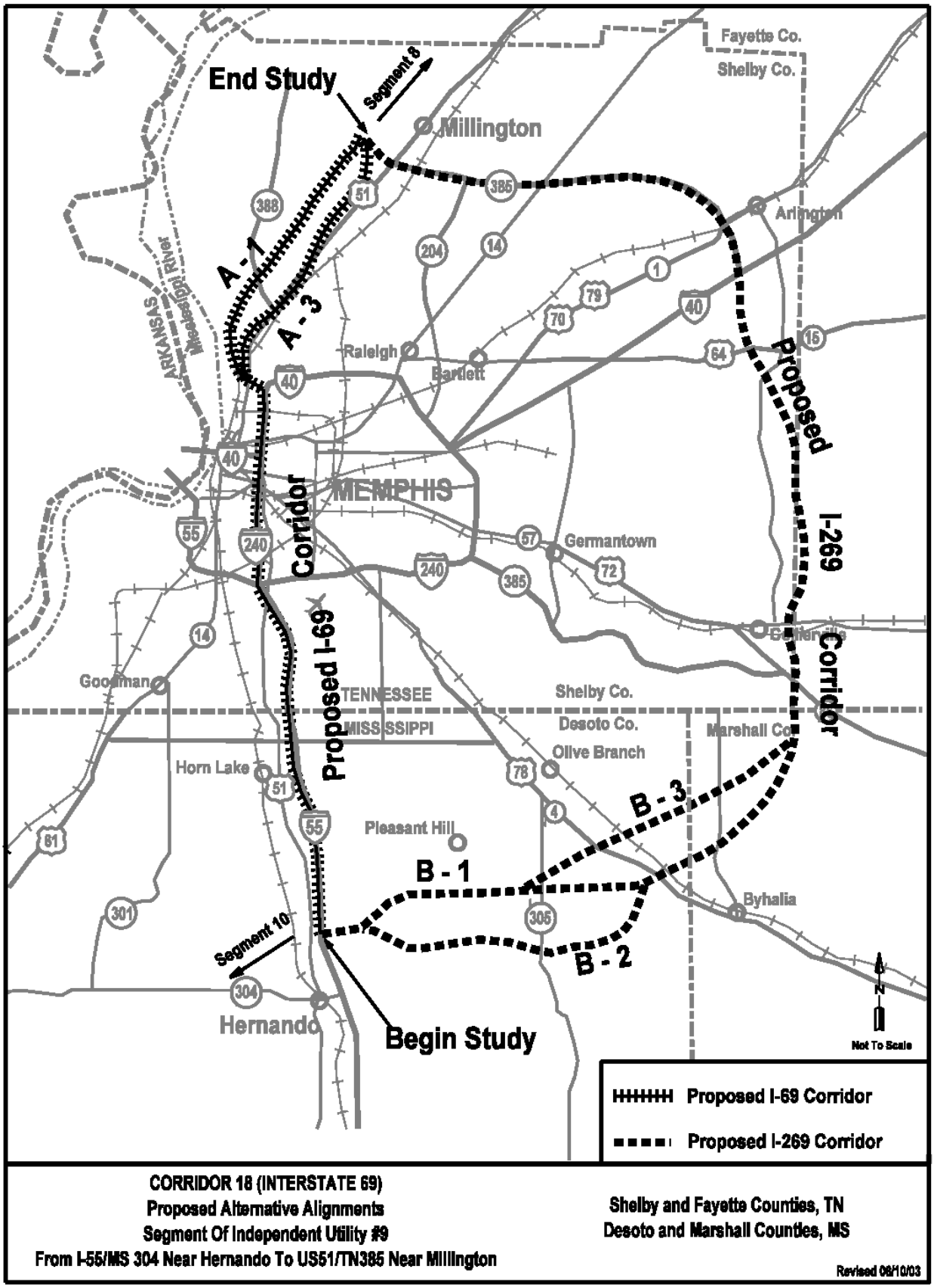
Therefore, the results of the Zero out run, which shows little contribution from DeSoto County to the monitors in Shelby and Crittenden Counties, are reliable.

DeSoto County – I-69 Questions

Questions were also raised regarding the impact of the I-69 project on DeSoto County. The I-69 project is still in the planning phase and complete information is not available. From discussions with the Mississippi Department of Transportation (MDOT), the earliest the project would be completed in the DeSoto County and Memphis area is 2012 to 2015. This is several years beyond the future year modeling and attainment dates for EAC and Traditional designations. This is also several years after implementation of the new low emission vehicle standards and the Heavy-Duty Diesel rule, which will significantly decease vehicle emissions.

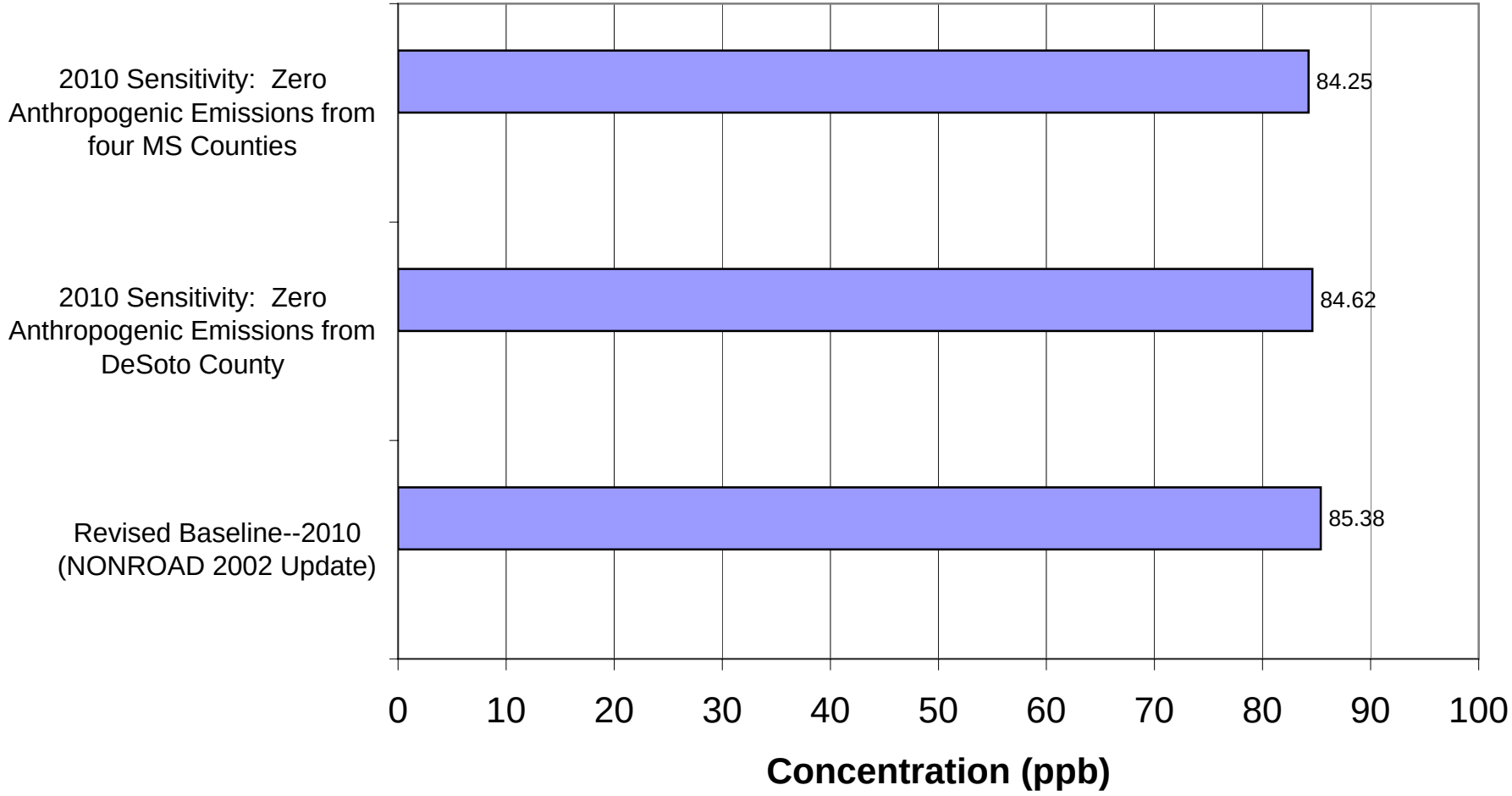
A Map of the proposed routes for I-69 in the Memphis area is attached. One proposed route uses existing I-55 as the corridor. The other route is an eastern loop that bypasses Memphis. It is difficult to anticipate the growth and development that will result from this project. While growth will occur, it is uncertain how significantly it will increase the growth in DeSoto County since the county already has significant roads connecting it to Memphis and the proposed routes do not open up new corridors for commuter traffic into Memphis from DeSoto County.

GENERAL LOCATION MAP

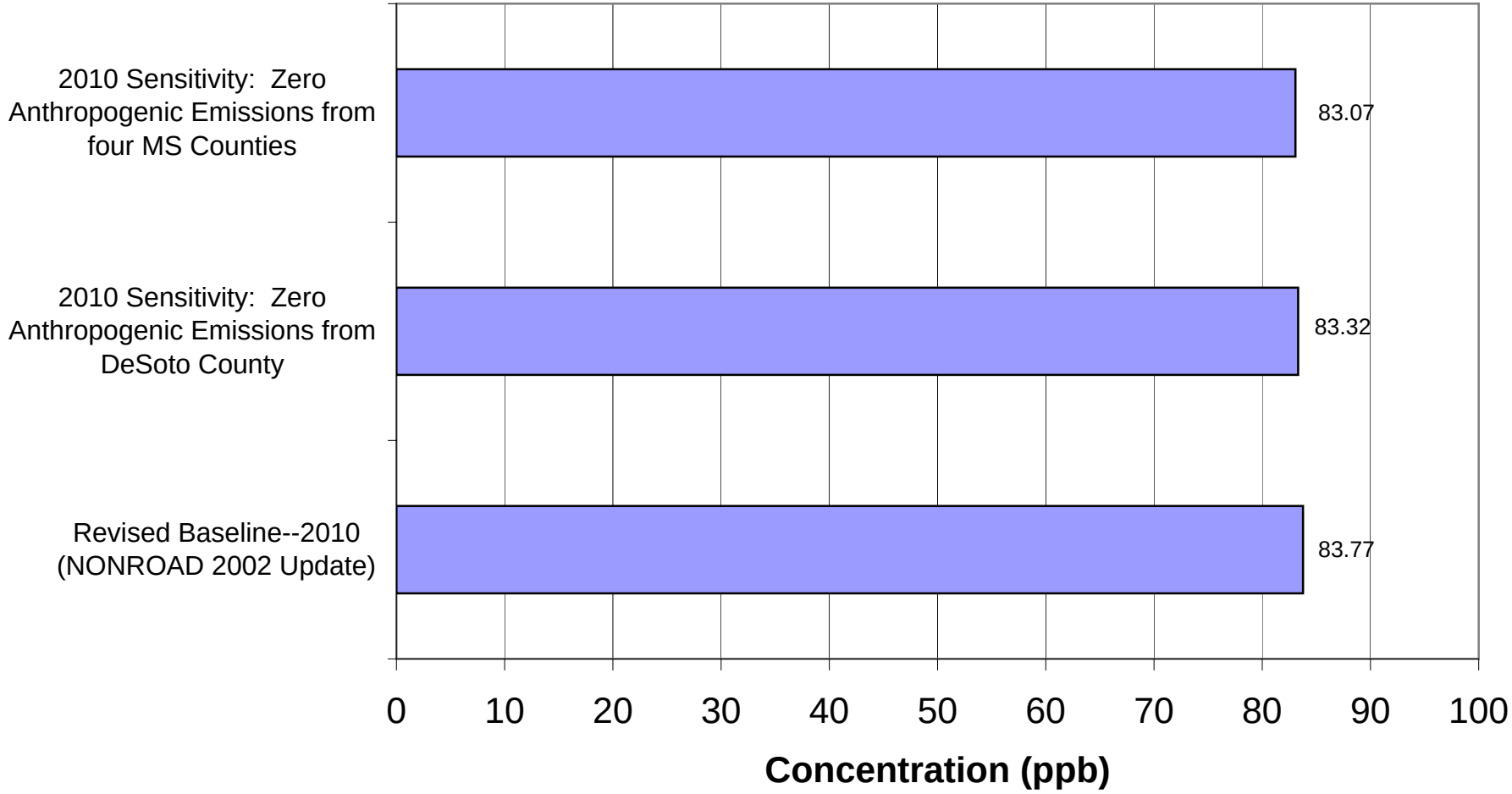


Map of proposed I-69 corridor, Section 9, from TDOT June 2003 Newsletter.doc. At this point in time, the most likely scenario would be the use of alternative corridor B-1/B-3. For more information, please visit the Tennessee Department of Transportation website at www.tdot.state.tn.us and click on "Hot Projects".

Estimated Design Value (99DV = 90 ppb) for 9-Cell Daily Peak 8-Hr Ozone (ppb) at the Marion, AR Monitor



Estimated Design Value (99DV = 95 ppb) for 9· Cell Daily Peak 8-Hr Ozone Concentration (ppb) at the Edmond Orgill Park, TN Monitor



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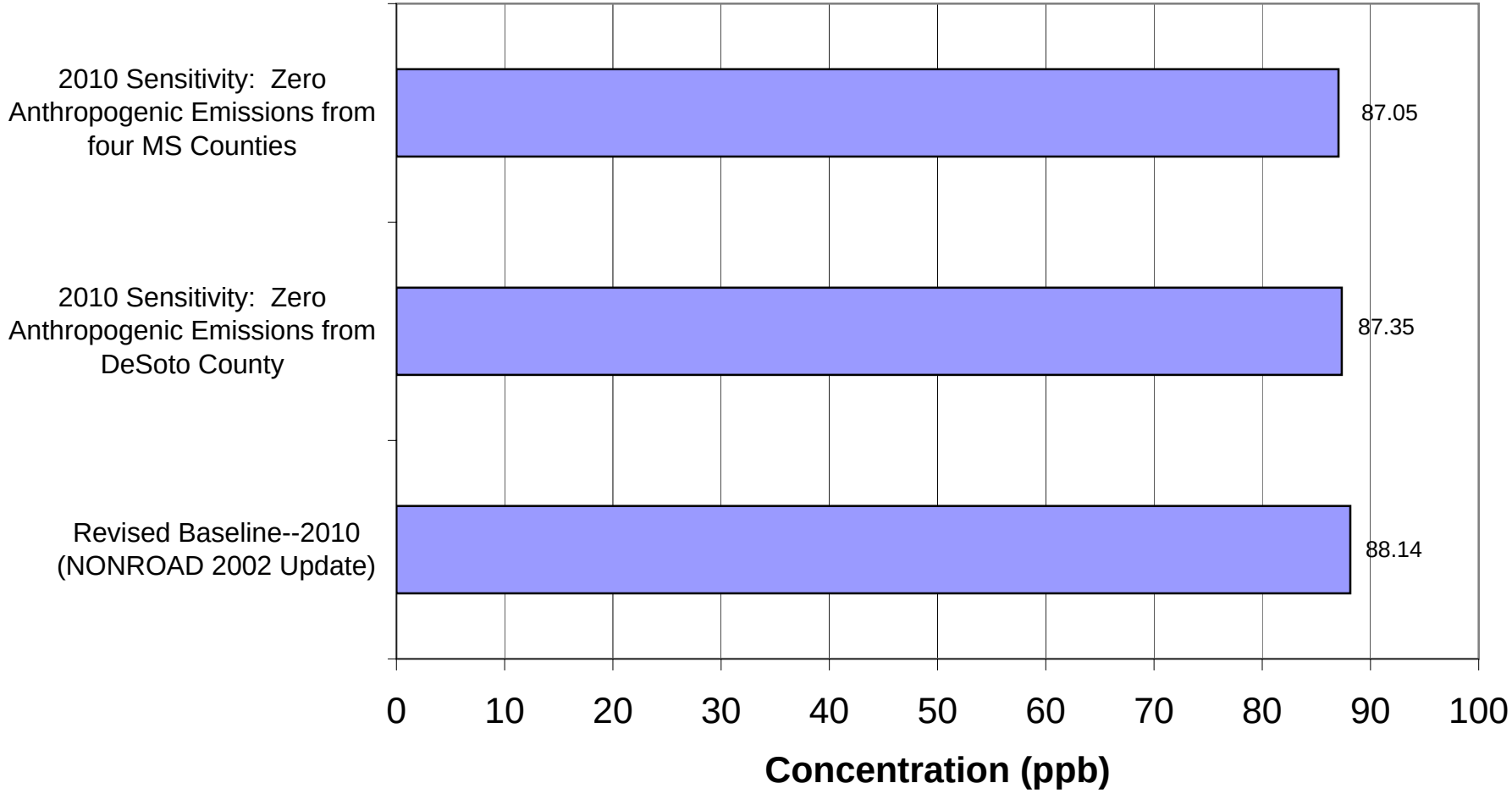

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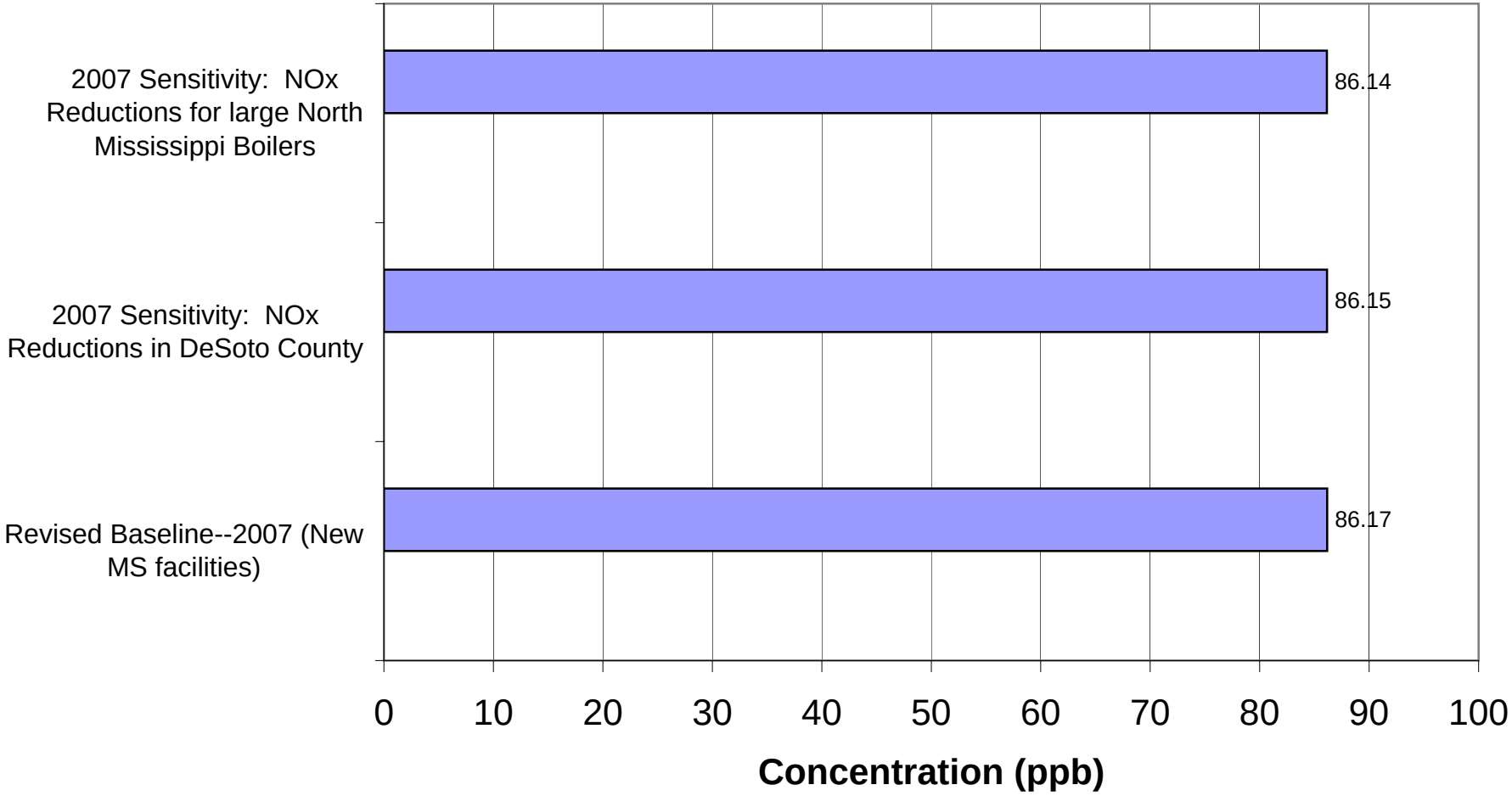

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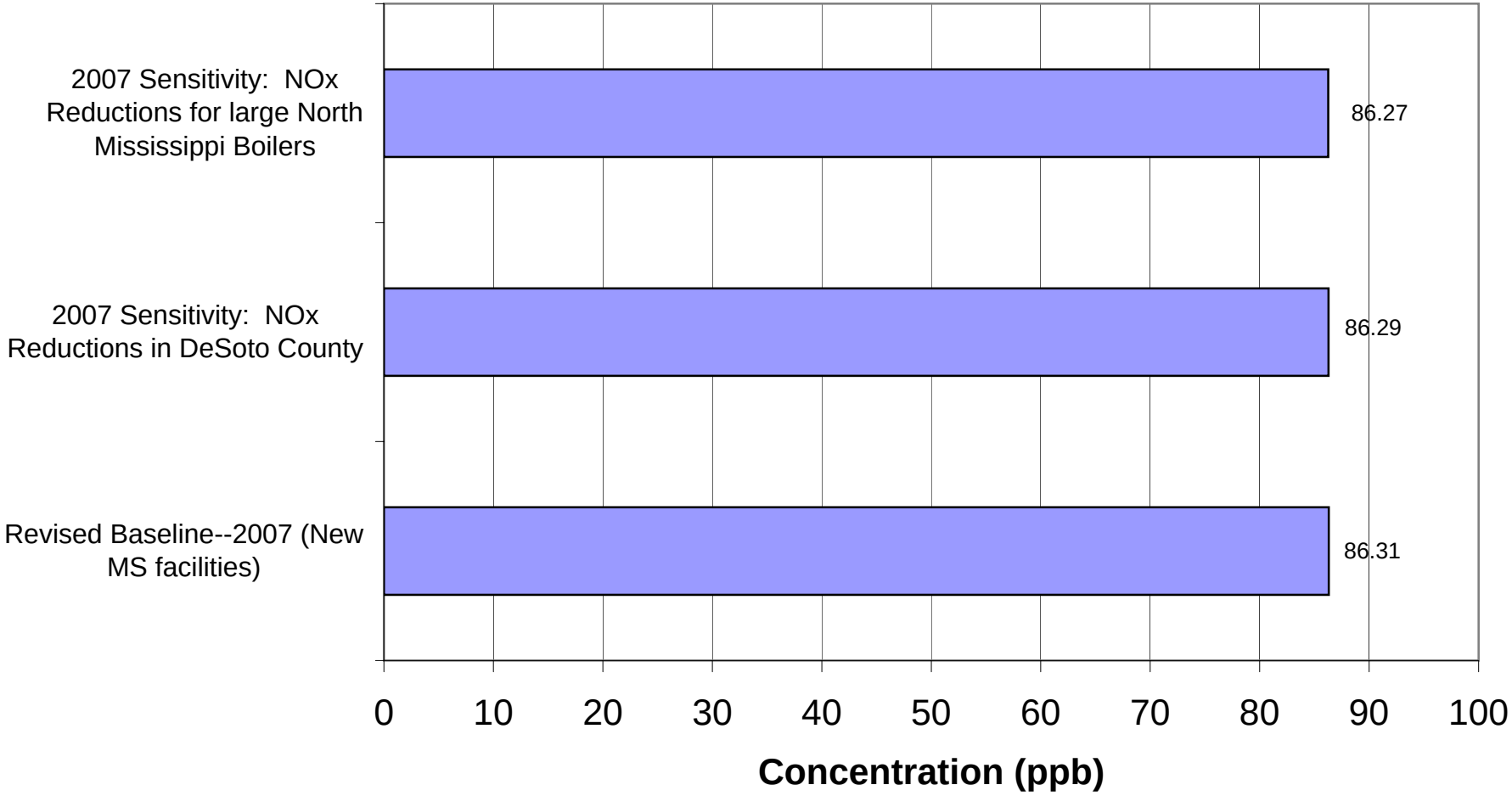

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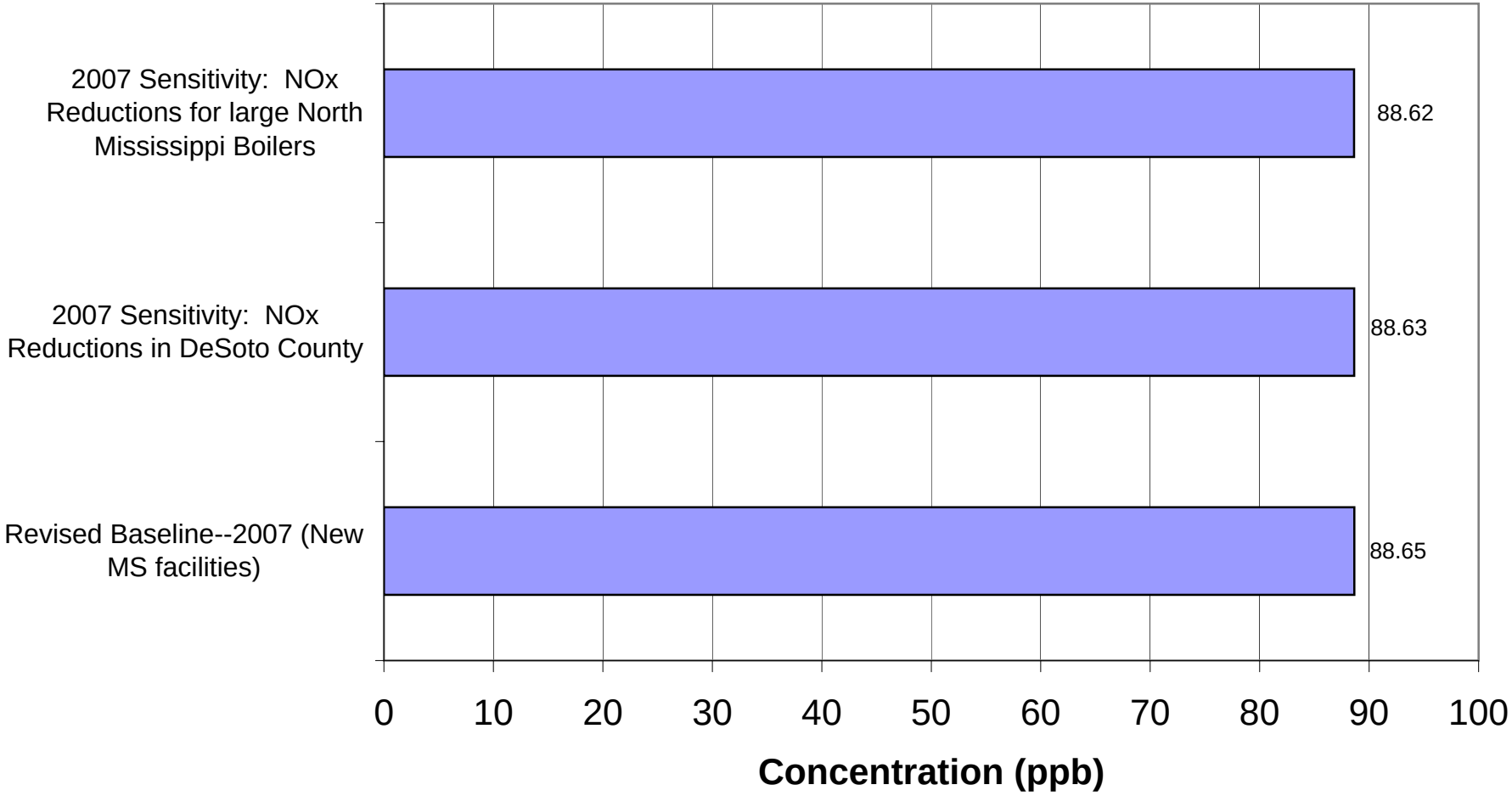
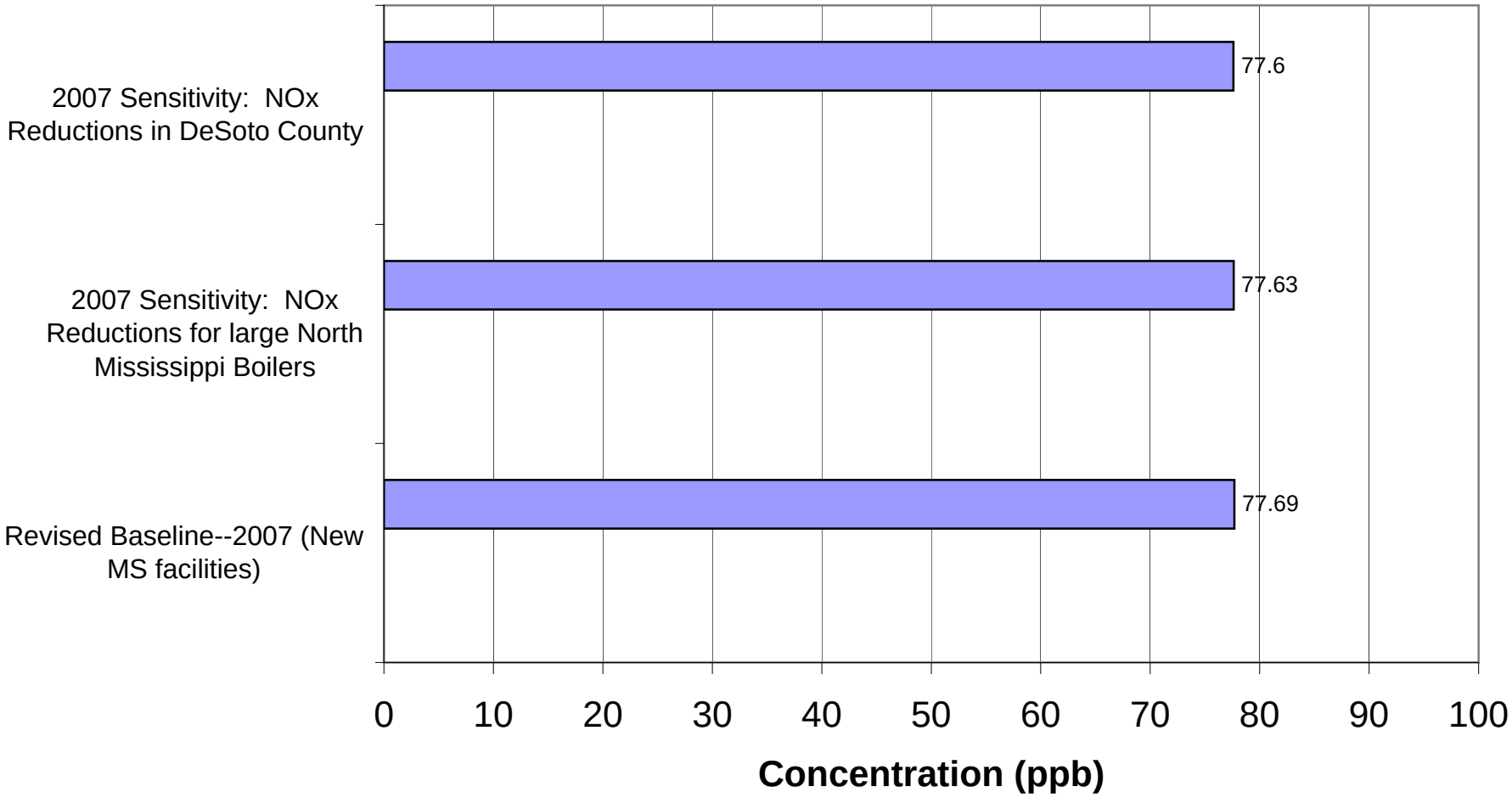
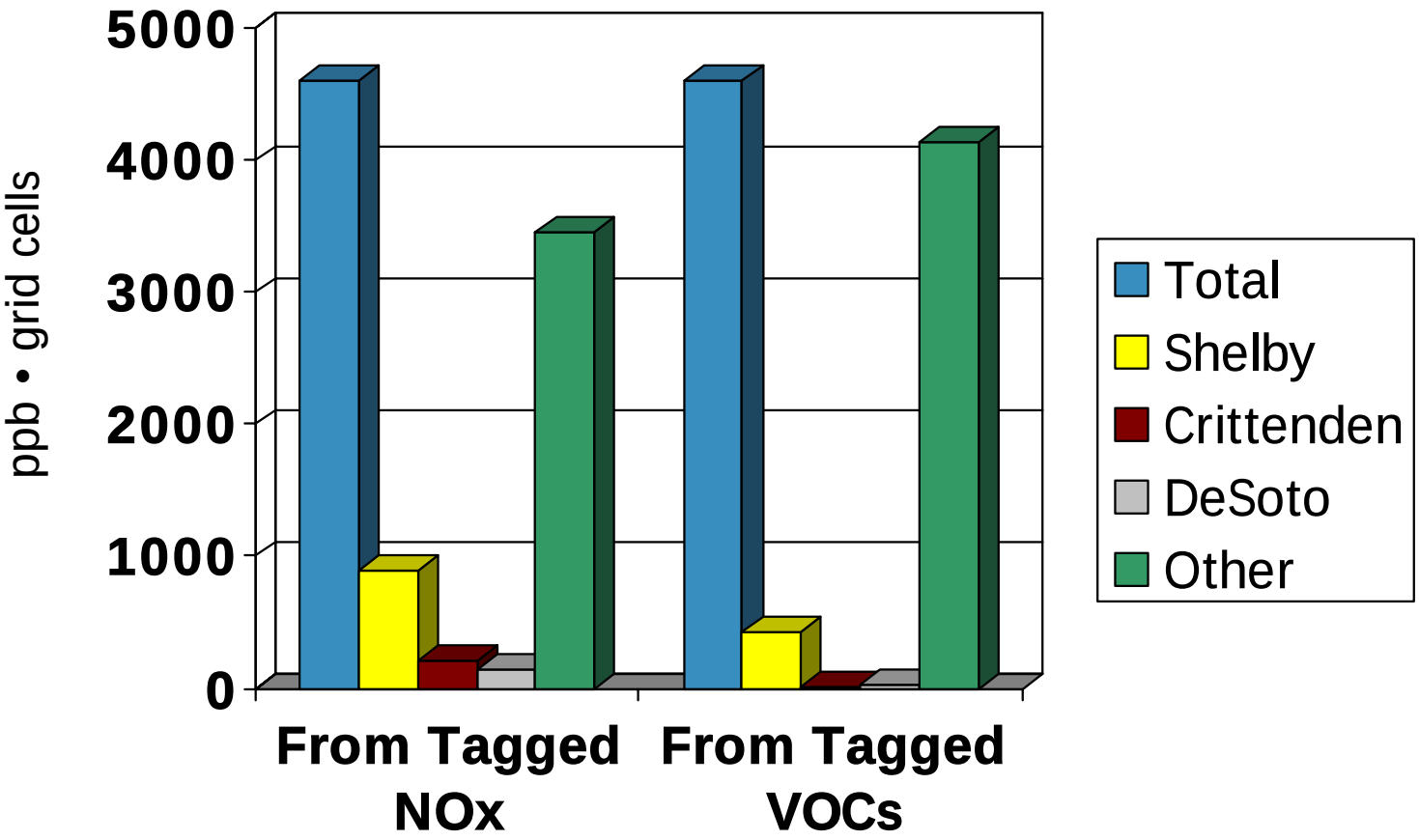


Estimated Design Value (99DV = 88 ppb) for 9-Cell Daily Peak 8-Hr Ozone Concentration (ppb) at the DeSoto County, MS Monitor



TOTAL 8-HOUR EXCEEDANCE EXPOSURE: SHELBY CO.

Aug/Sep (1999) and June (2001) Simulation Periods Combined: 2007 Baseline



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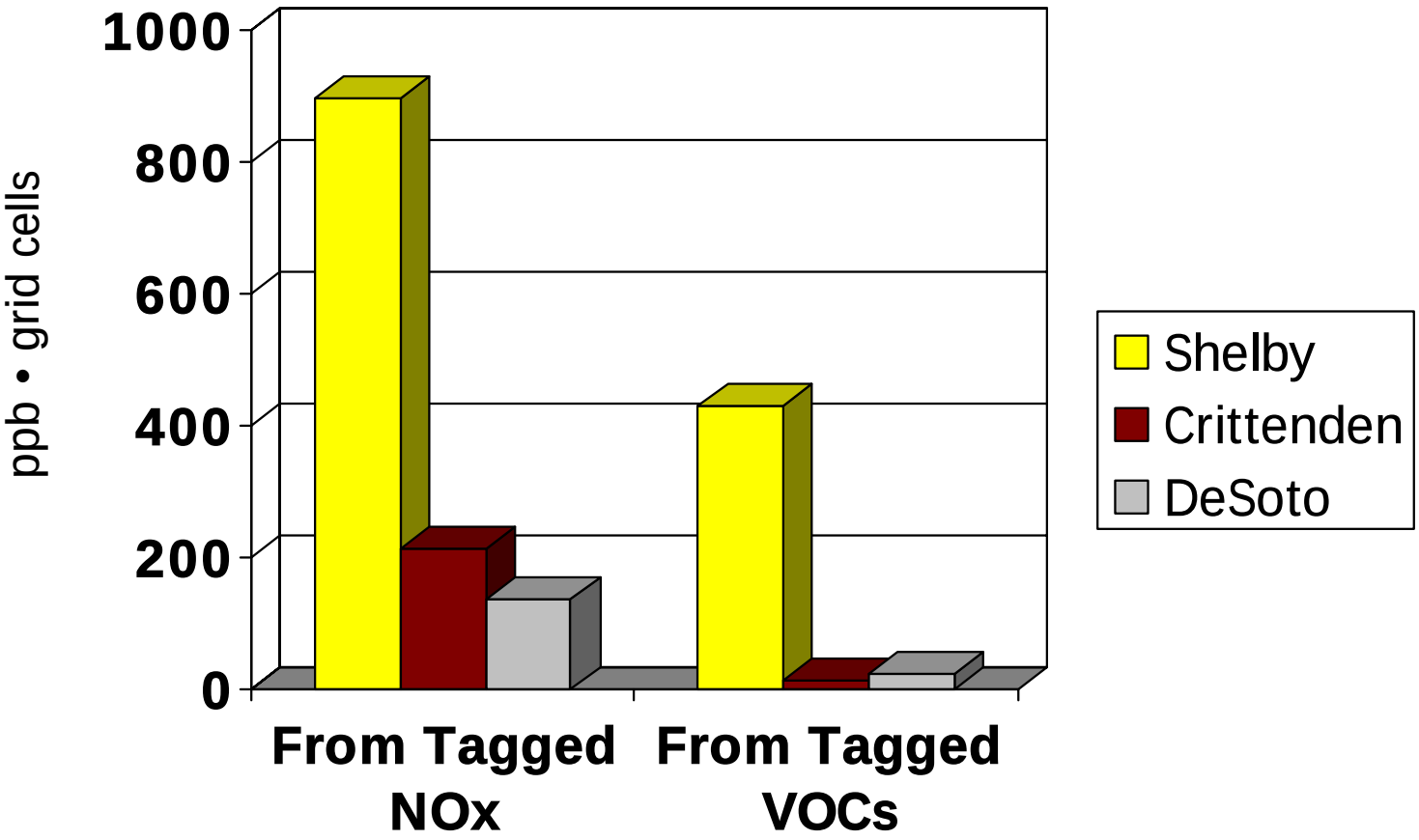
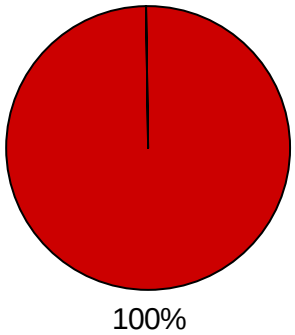


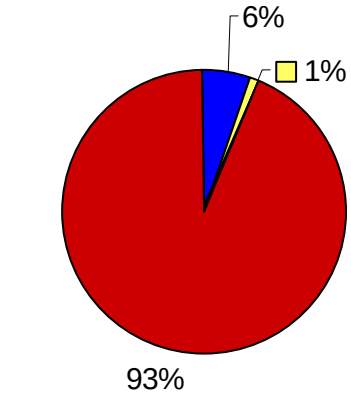
EDMUND ORGILL PARK
MAX 8-HR O3 FROM VOC/NOX

11:00 Sep. 3

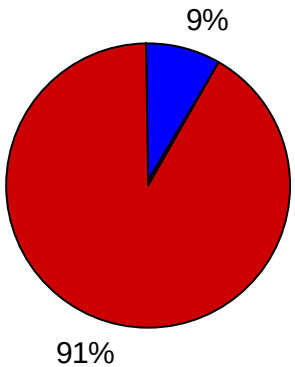
12:00 Sep. 4

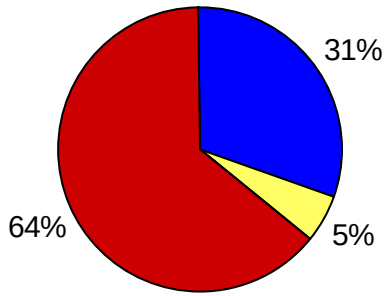
VOC





NOX





Emissions:

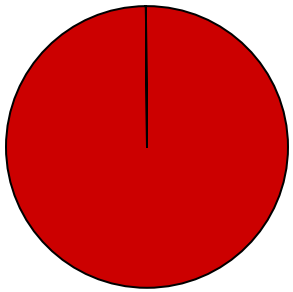
- **Shelby anthropogenic**
- **Crittenden anthropogenic**
- **DeSoto anthropogenic**
- **All other**

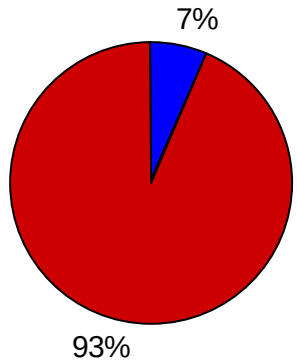
EDMUND ORGILL PARK
MAX 8-HR O3 FROM VOC/NOX

12:00 June 18

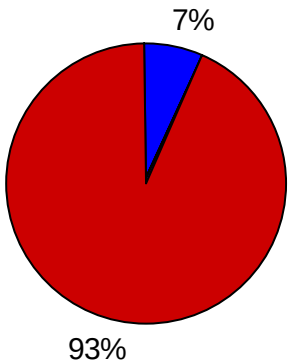
12:00 June 20

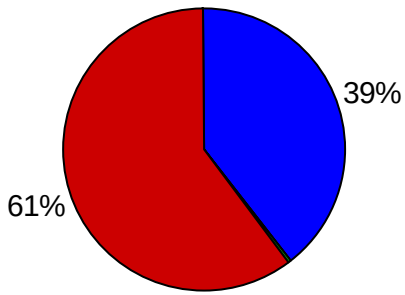
VOC





NOX



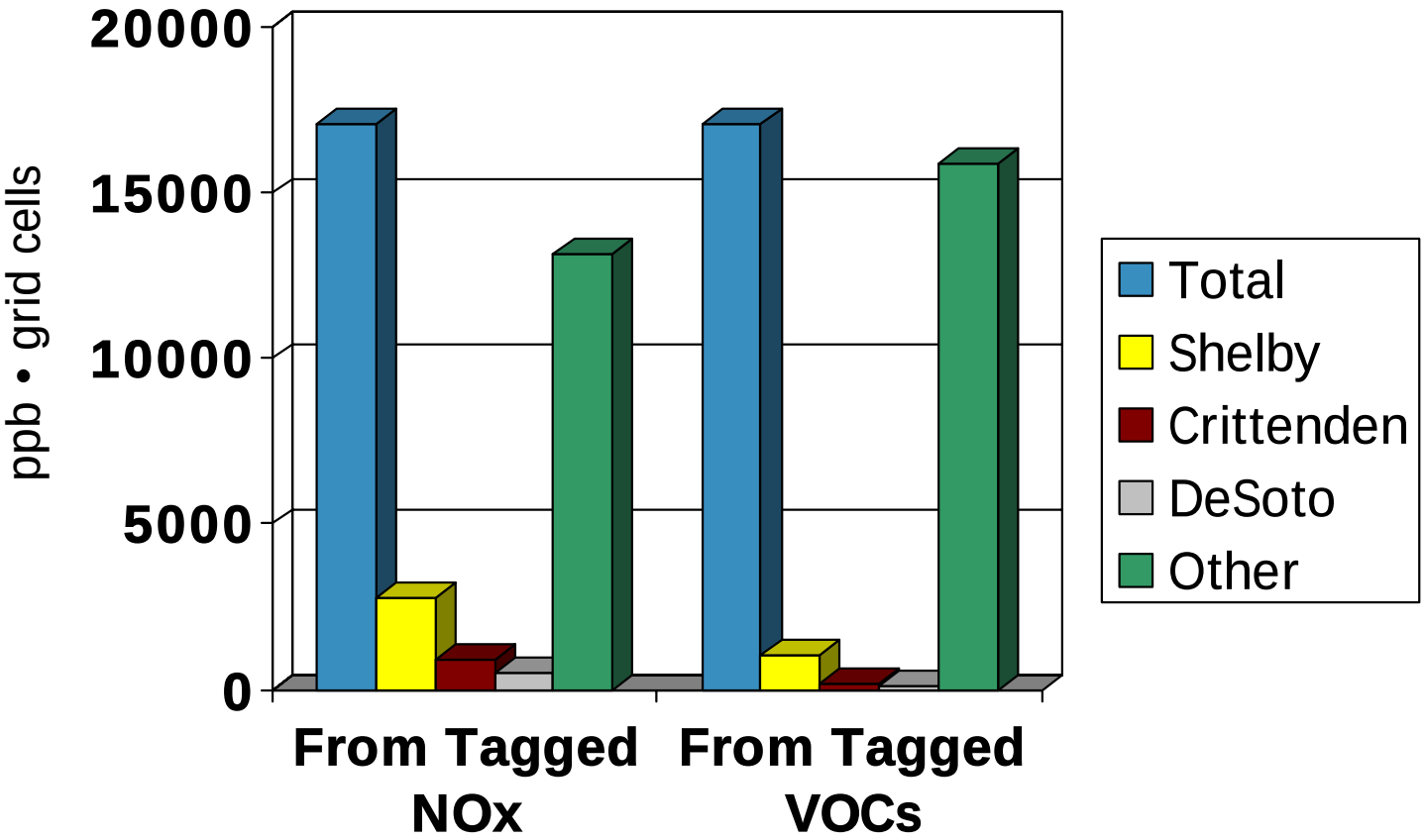


Emissions:

- **Shelby anthropogenic**
- **Crittenden anthropogenic**
- **DeSoto anthropogenic**
- **All other**

TOTAL 8-HOUR EXCEEDANCE EXPOSURE: CRITTENDEN CO.

Aug/Sep (1999) and June (2001) Simulation Periods Combined: 2007 Baseline



TOTAL 8-HOUR EXCEEDANCE EXPOSURE: CRITTENDEN CO.

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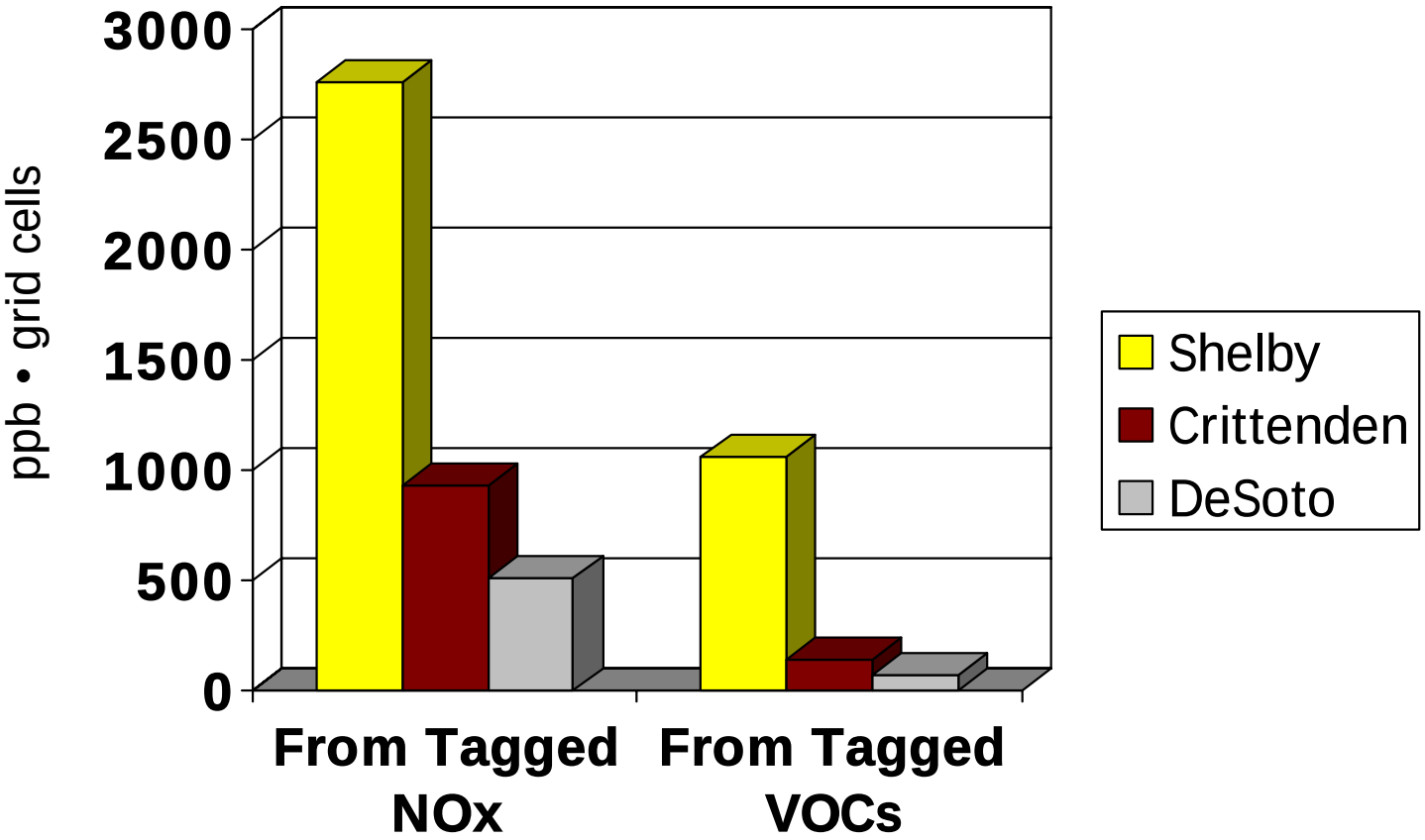
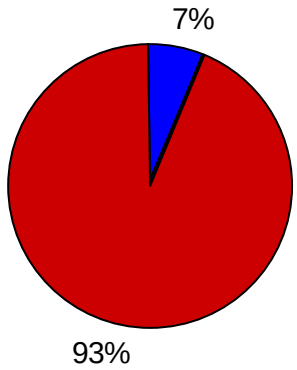


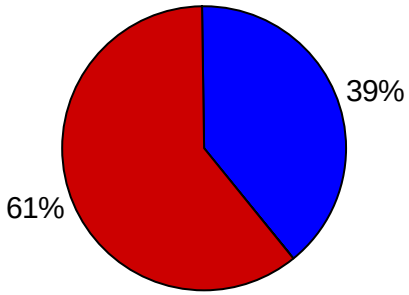
MARION
MAX 8-HR O3 FROM VOC/NOX

VOC

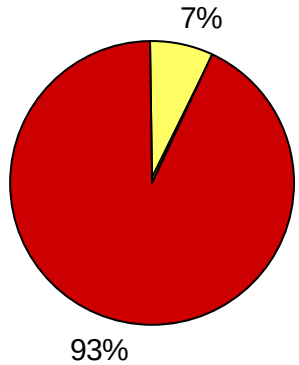
NOX

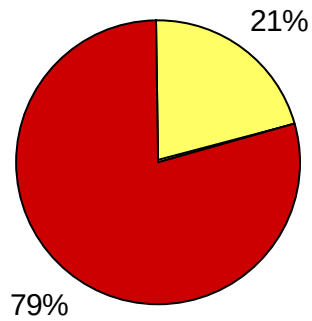
11:00 Sep. 3





12:00 Sep. 4





Emissions:

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- **DeSoto anthropogenic**
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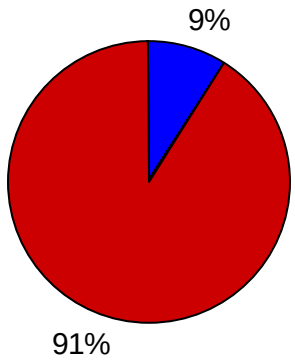
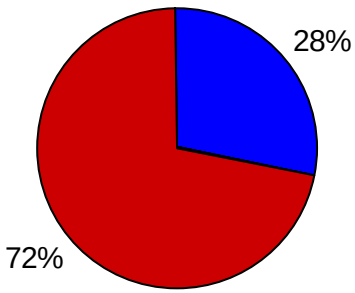
MARION
MAX 8-HR O3 FROM VOC/NOX

VOC

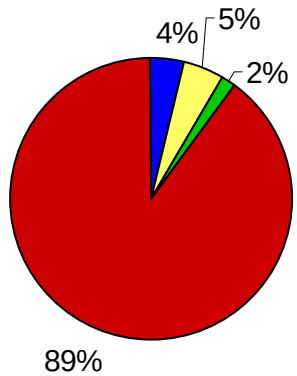
NOX

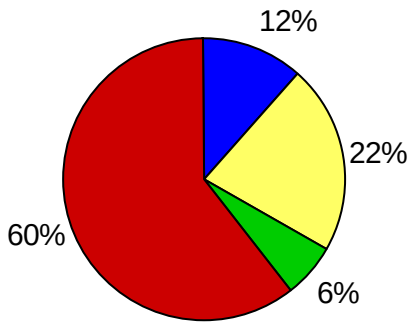
10:00 June 18





11:00 June 20





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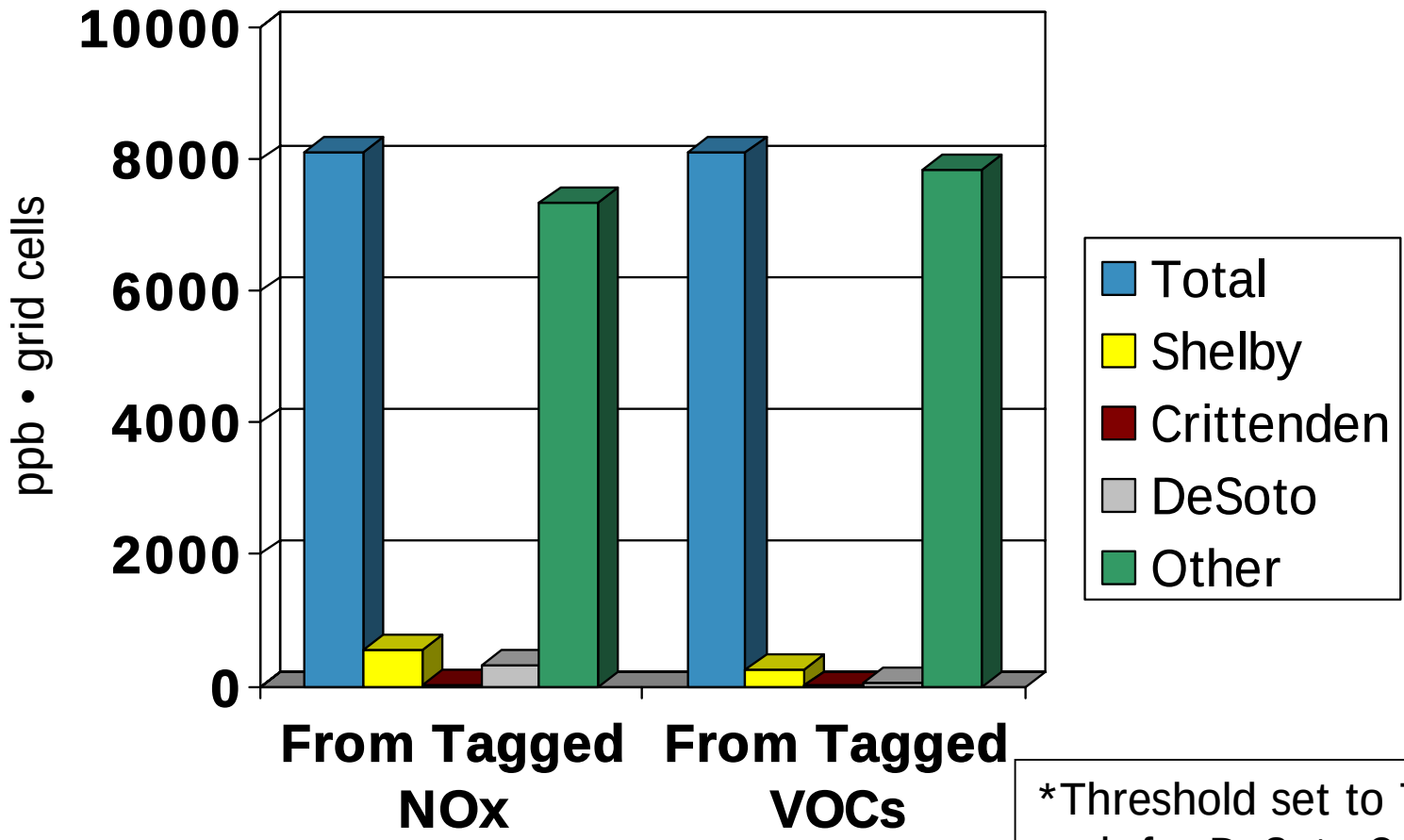

*Threshold set to 70 ppb for DeSoto Co.

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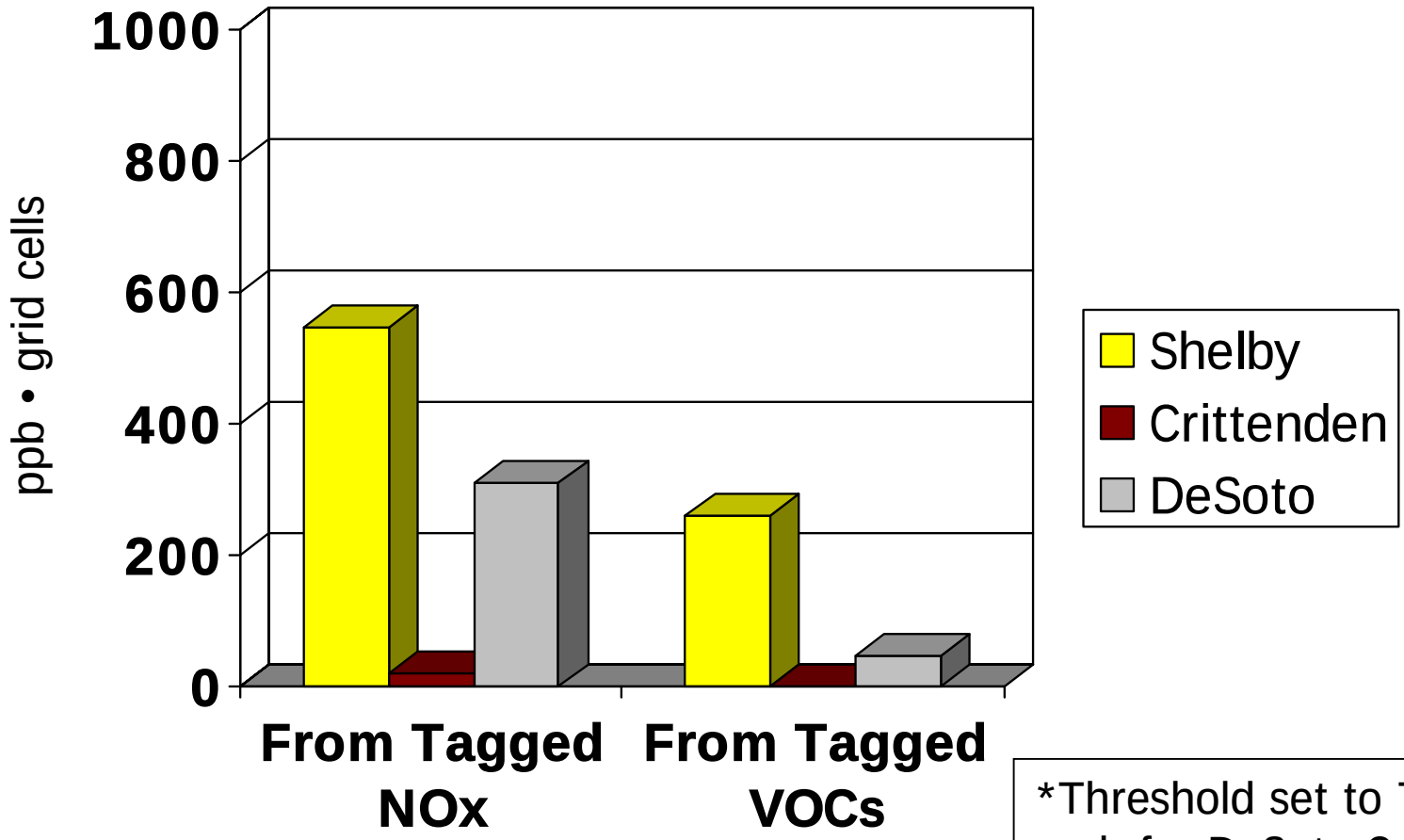

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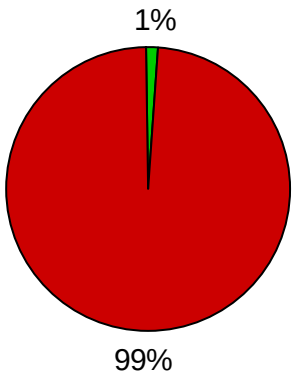
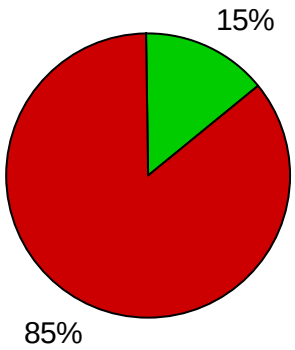
DESOTO COUNTY
MAX 8-HR O3 FROM VOC/NOX

VOC

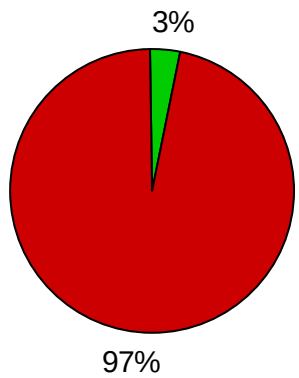
NOX

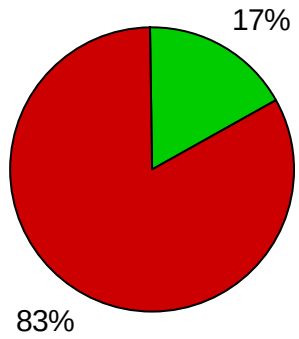
11:00 Sep. 3





12:00 Sep. 4





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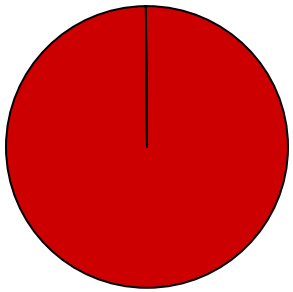
- **DeSoto anthropogenic**
- **All other**

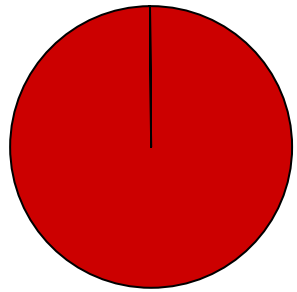
DESOTO COUNTY
MAX 8-HR O3 FROM VOC/NOX

11:00 June 18

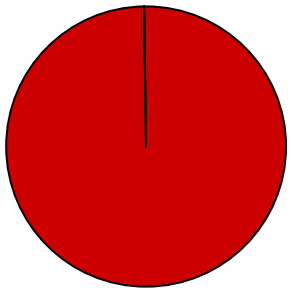
11:00 June 20

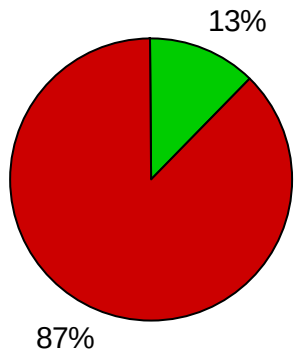
VOC





NOX





Emissions:

- **Shelby anthropogenic**
- **Crittenden anthropogenic**
- **DeSoto anthropogenic**
- **All other**

Back Trajectory Information

- Attached are back trajectories for the Marion, Arkansas; Memphis, Tennessee; Edmond Orgill Park, Tennessee; and Hernando, Mississippi ozone monitoring sites. Also attached is a map showing the locations of the monitoring sites.

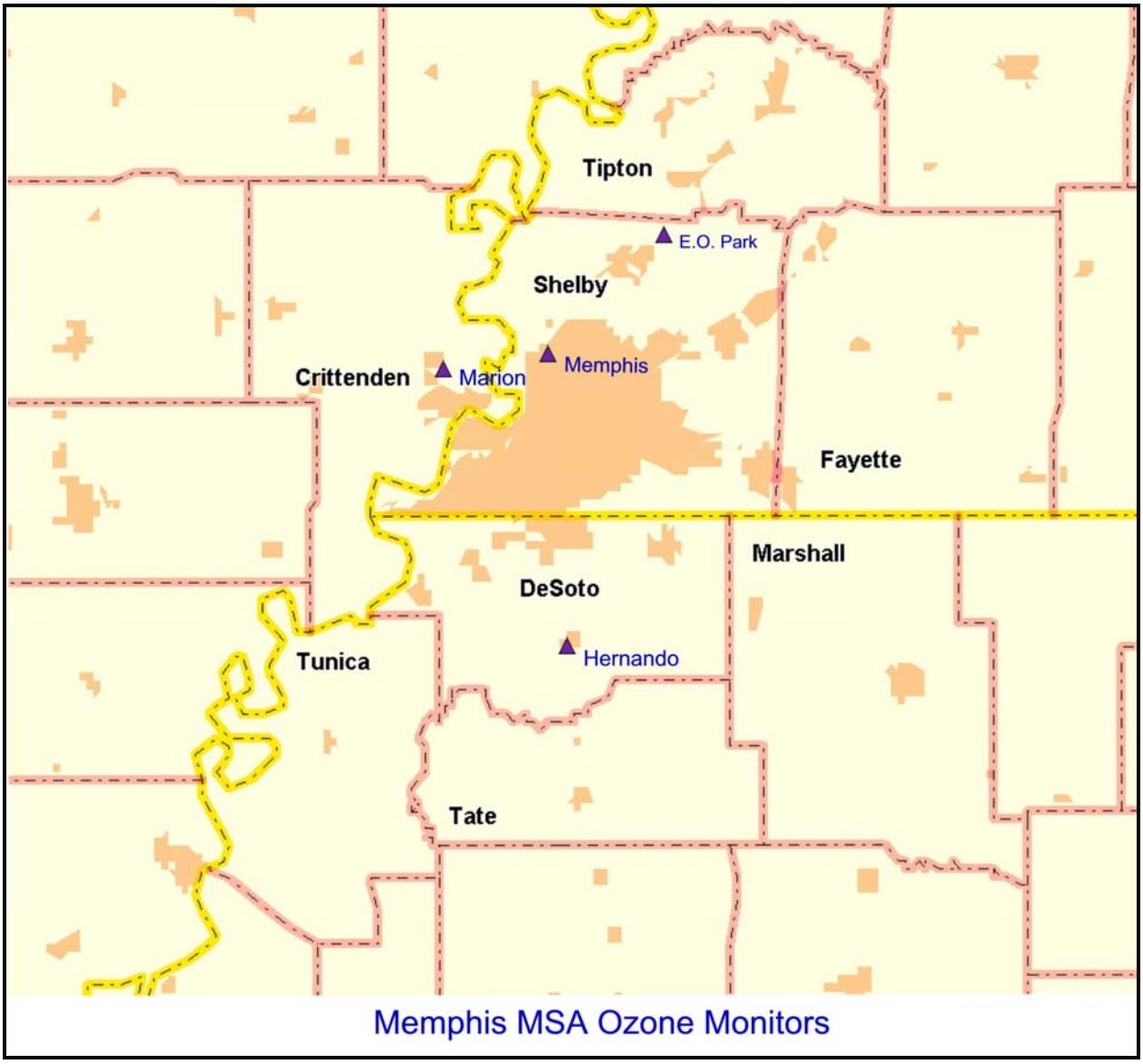
- The back trajectories shown were chosen because the highest 8-hour ozone concentrations for the years 1997-2003 occurred on those days.

- The duration of each back trajectory is 48 hours and ends at 3:00 p.m. on the day that the high 8-hour ozone concentration was reported.

- The trajectories were run at 10 meters above ground level.

- Where possible, the archived data used to run the trajectories came from the Eta Data Assimilation System (EDAS) because it is based on a finer spatial resolution than the FNL. The other trajectories were run using the Final (FNL) Run of the Global Data Assimilation System.

Map of Memphis MSA Ozone Monitors



Back Trajectory Summary

- 22 back trajectories are shown for Marion, Arkansas; 17 back trajectories are shown for Memphis, Tennessee; 19 back trajectories are shown for Edmond Orgill Park, Tennessee; and 20 back trajectories are shown for Hernando, Mississippi.

- The air flow was considered stagnant (<5 mph average) if the back trajectories have a length of 200-240 miles or less.

Marion, Arkansas Ozone Monitoring Site

- 7 of the 22 (27%) back trajectories show stagnant conditions.
- 6 of the 15 (40%) non-stagnant back trajectories show that the air flowed generally from the east and southeast through DeSoto County and Shelby County prior to arriving at the monitoring site.
- 8 of the 15 (93%) non-stagnant back trajectories show that the air flowed generally northeast and east through Shelby County and not through DeSoto County prior to arriving at the monitoring site.
- The other non-stagnant back trajectory (7%) shows that the air flowed from the west.

Memphis, Tennessee Ozone Monitoring Site

- 6 of the 17 (35%) back trajectories show stagnant conditions.
- 2 of the 11 (18%) non-stagnant back trajectories show that the air flowed generally from the south and southeast through DeSoto County and much of Memphis prior to arriving at the monitoring site.
- 4 of the 11 (36%) non-stagnant back trajectories show that the air flowed generally from the southwest, west, and northwest through Crittenden County prior to arriving at the monitoring site.
- The other 5 of the 11 (45%) non-stagnant back trajectories show that the air flowed from the north and northeast.

Edmond Orgill Park, Tennessee Ozone Monitoring Site

- 9 of the 19 (47%) back trajectories show stagnant conditions.
- 2 of the 10 (20%) non-stagnant back trajectories show that the air flowed generally from the south, southeast, and southwest through DeSoto County and Memphis prior to arriving at the monitoring site.
- 1 of the 10 (10%) non-stagnant back trajectories shows that the air flowed from the west through Crittenden County prior to arriving at the monitoring site.
- The other 7 of 10 (70%) non-stagnant back trajectories show that the air flowed from the north, northeast, and northwest.

Hernando, Mississippi Ozone Monitoring Site

- 8 of the 20 (40%) back trajectories show stagnant conditions.
- 8 of the 12 (67%) non-stagnant back trajectories show that the air flowed generally from the north and northeast through Shelby County and the northern part of DeSoto County prior to arriving at the monitoring site.
- 1 of the 12 (8%) non-stagnant back trajectories shows that the air flowed from the southwest through Crittenden County and the western part of DeSoto County prior to arriving at the monitoring site.
- The other 3 of the 12 (25%) non-stagnant back trajectories show that the air flowed from the east.

List of Back Trajectories

Marion, Arkansas Ozone Monitoring Site

1997 – 1st Max – 100 ppb – July 17
1997 – 2nd Max – 97 ppb – July 20

1998 – 1st Max – 92 ppb – May 20
1998 – 2nd Max – 90 ppb – August 22

1999 – 1st Max – 104 ppb – July 8
1999 – 2nd Max – 99 ppb – August 27

2000 – 1st Max – 96 ppb – August 14
2000 – 2nd Max – 95 ppb – July 26

2001 – 1st Max – 102 ppb – July 6
2001 – 2nd Max – 98 ppb – August 2

2002 – 1st Max – 107 ppb – June 21
2002 – 2nd Max – 106 ppb – May 31
2002 – 3rd Max – 101 ppb – August 3
2002 – 4th Max – 100 ppb – July 8
2002 – 5th Max – 97 ppb – June 18
2002 – 6th Max – 89 ppb – August 4
2002 – 7th Max – 88 ppb – June 22
2002 – 8th Max – 87 ppb – September 6

2003 – 1st Max – 108 ppb – June 23
2003 – 2nd Max – 96 ppb – May 24
2003 – 3rd Max – 92 ppb – August 25
2003 – 4th Max – 90 ppb – September 17

Memphis, Tennessee Ozone Monitoring Site

1997 – 1st Max – 107 ppb – July 3
1997 – 2nd Max – 96 ppb – September 18

1998 – 1st Max – 123 ppb – May 18
1998 – 2nd Max – 94 ppb – August 23

1999 – 1st Max – 110 ppb – July 8
1999 – 2nd Max – 106 ppb – September 4

2000 – 1st Max – 106 ppb – June 26
2000 – 2nd Max – 104 ppb – August 22

2001 – 1st Max – 114 ppb – June 12
2001 – 2nd Max – 93 ppb – June 20

2002 – 1st Max – 93 ppb – August 1
2002 – 2nd Max – 91 ppb – June 21
2002 – 3rd Max – 88 ppb – July 8
2002 – 4th Max – 86 ppb – September 6
2002 – 5th Max – 85 ppb – August 3

2003 – 1st Max – 94 ppb – June 23
2003 – 2nd Max – 87 ppb – August 20

Edmond Orgill Park, Tennessee Ozone Monitoring Site

1997 – 1st Max – 98 ppb – September 15
1997 – 2nd Max – 89 ppb – July 3

1998 – 1st Max – 108 ppb – August 23
1998 – 2nd Max – 108 ppb – August 28

1999 – 1st Max – 102 ppb – September 19
1999 – 2nd Max – 100 ppb – August 7

2000 – 1st Max – 98 ppb – August 15
2000 – 2nd Max – 98 ppb – September 18

2001 – 1st Max – 101 ppb – August 24
2001 – 2nd Max – 95 ppb – July 25

2002 – 1st Max – 92 ppb – June 21
2002- 2nd Max – 91 ppb – July 8
2002 – 3rd Max – 89 ppb – September 5
2002 – 4th Max – 88 ppb – July 9
2002 – 5th Max – 88 ppb – September 10
2002 – 6th Max – 86 ppb – August 10

2003 – 1st Max – 91 ppb – July 14
2003 – 2nd Max – 90 ppb – July 20
2003 – 3rd Max – 89 ppb – August 22

Hernando, Mississippi Ozone Monitoring Site

1997 – 1st Max – 108 ppb – July 20
1997 – 2nd Max – 99 ppb – August 3
1997 – 3rd Max – 86 ppb – July 24

1998 – 1st Max – 99 ppb – August 18
1998 – 2nd Max – 96 ppb – August 16
1998 – 3rd Max – 95 ppb – May 18
1998 – 4th Max – 89 ppb – May 21

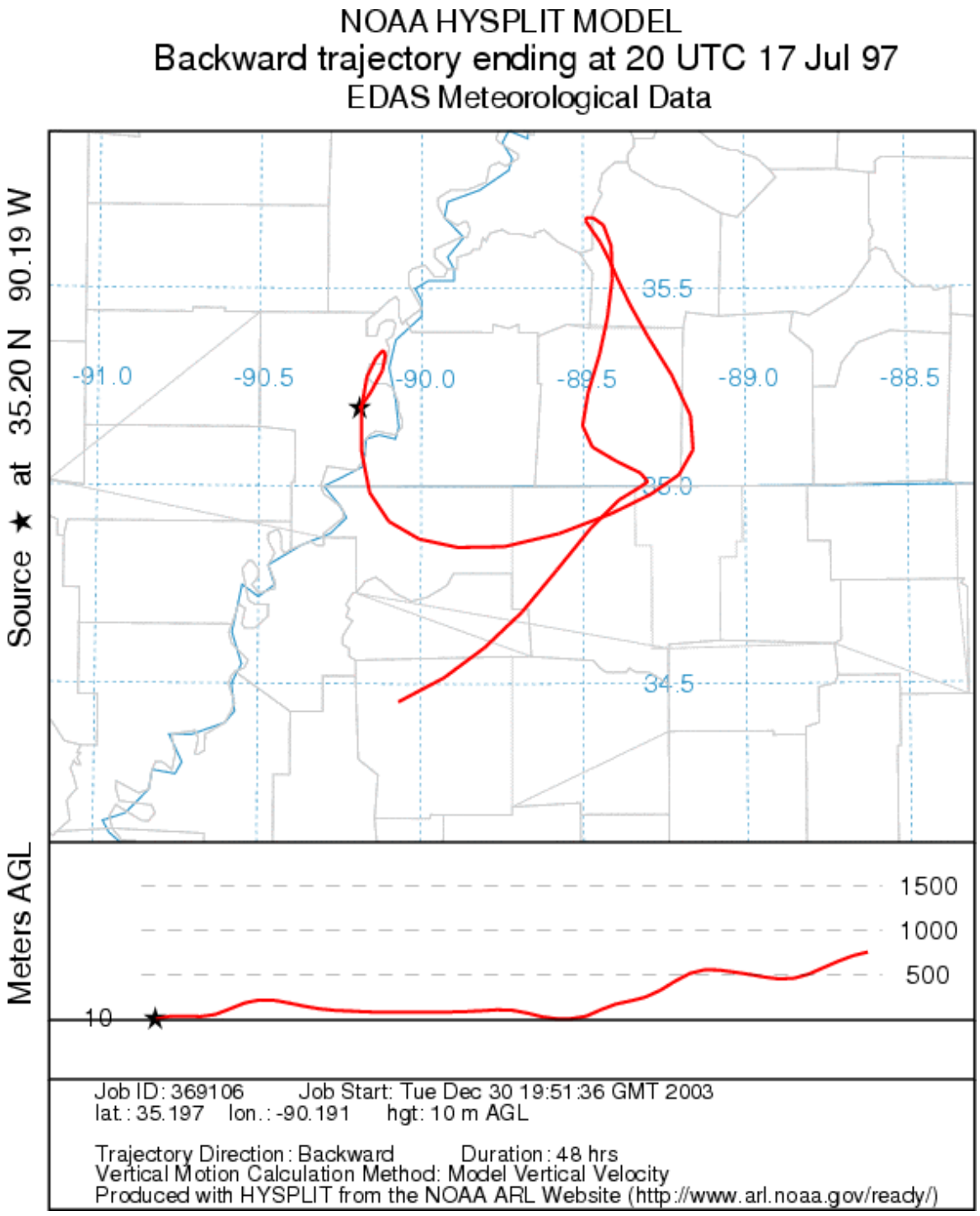
1999 – 1st Max – 108 ppb – August 18
1999 – 2nd Max – 100 ppb – August 17
1999 – 3rd Max – 97 ppb – August 4
1999 – 4th Max – 93 ppb – August 6

2000 – 1st Max – 96 ppb – July 16
2000 – 2nd Max – 95 ppb – August 31
2000 – 3rd Max – 92 ppb – August 29
2000 – 4th Max – 92 ppb – August 30

2002 – 1st Max – 103 ppb – September 13
2002 – 2nd Max – 102 ppb – September 10
2002 – 3rd Max – 95 ppb – August 8
2002 – 4th Max – 91 ppb – August 3

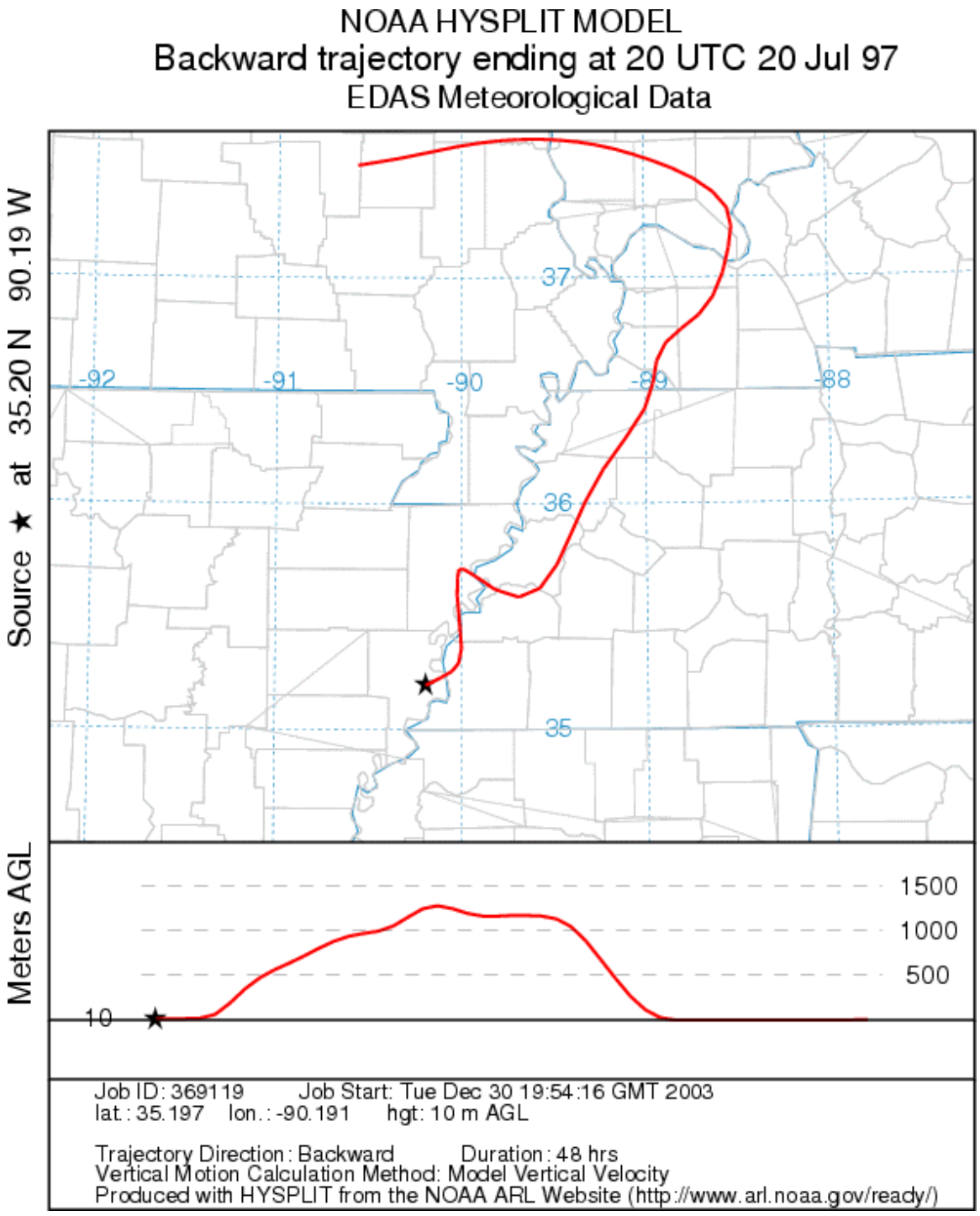
2003 – 1st Max – 86 ppb – April 13

Marion, Arkansas Monitor 48-Hour Back Trajectory for the Period Ending July 17, 1997
Maximum 8-Hour Average – 100 ppb – 1st Max



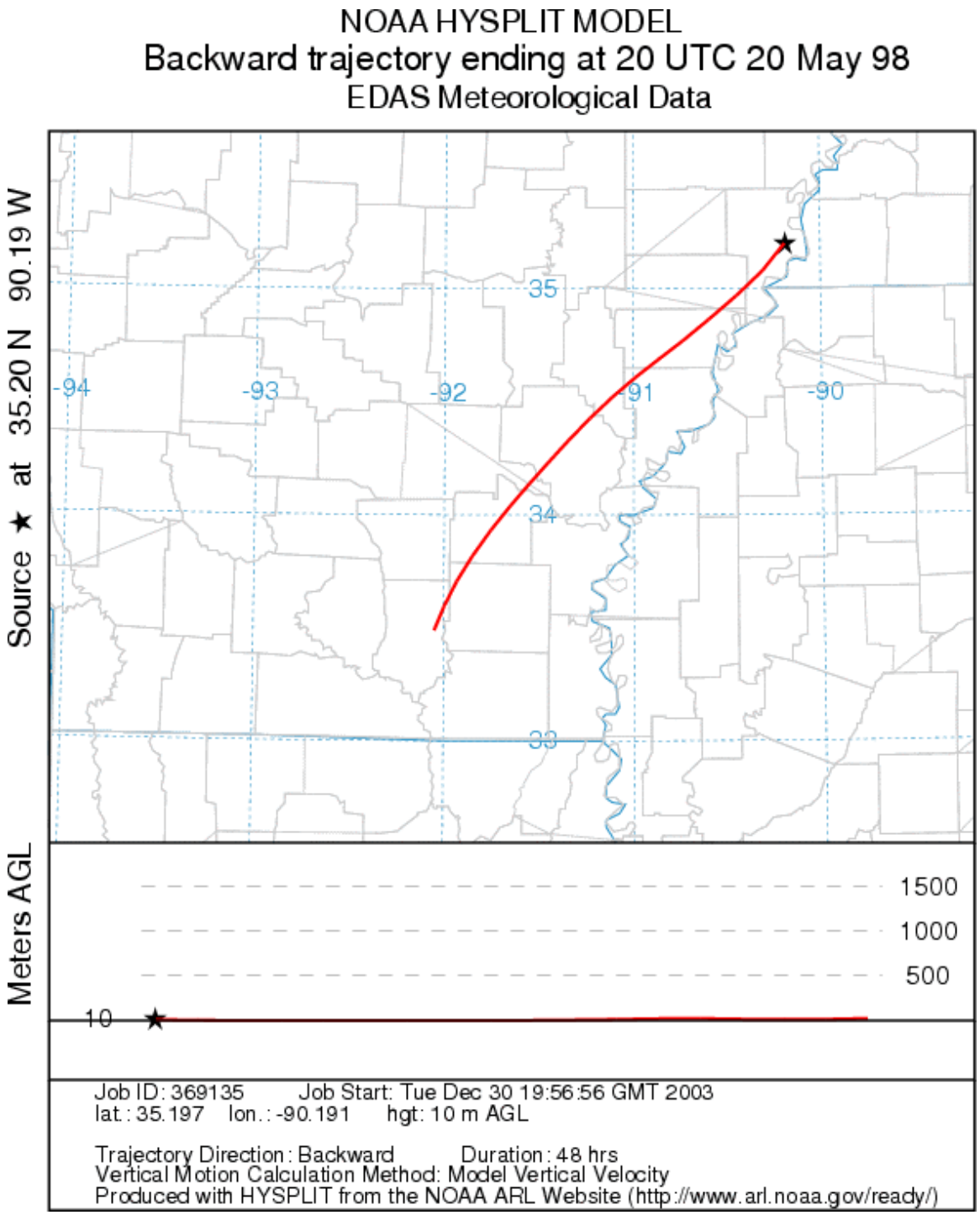
Light and variable transport winds flowing through western Tennessee and northern Mississippi before arriving at the Marion ozone monitor.

Marion, Arkansas Monitor 48-Hour Back Trajectory for the Period Ending July 20, 1997
Maximum 8-Hour Average – 97 ppb – 2nd Max



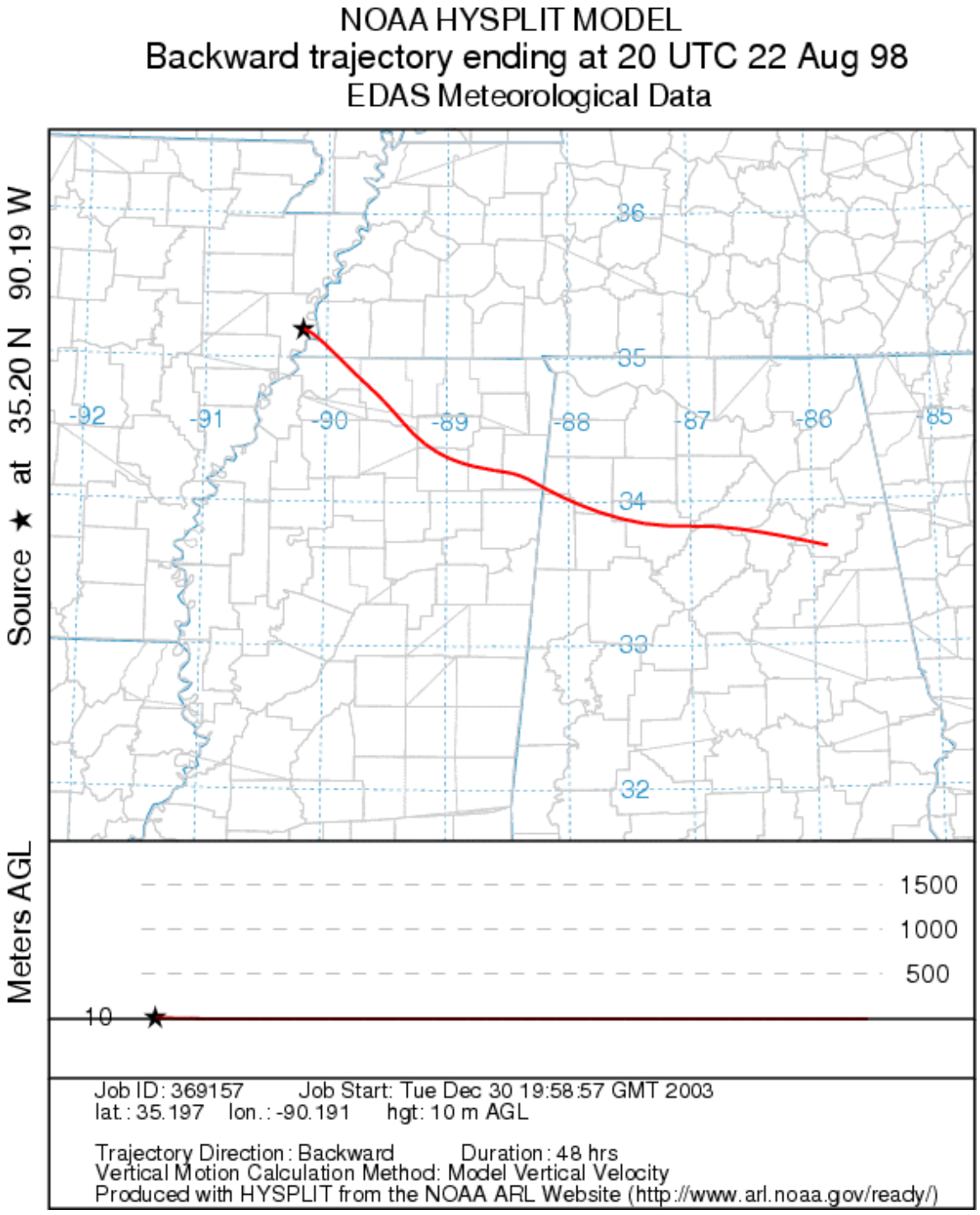
Light northeasterly transport winds originating in southeastern Missouri and flowing through southern Illinois, western Kentucky, and western Tennessee before arriving at the Marion ozone monitor. **Marion,**

Arkansas Monitor 48-Hour Back Trajectory for the Period Ending May 20, 1998
Maximum 8-Hour Average – 92 ppb 1st Max



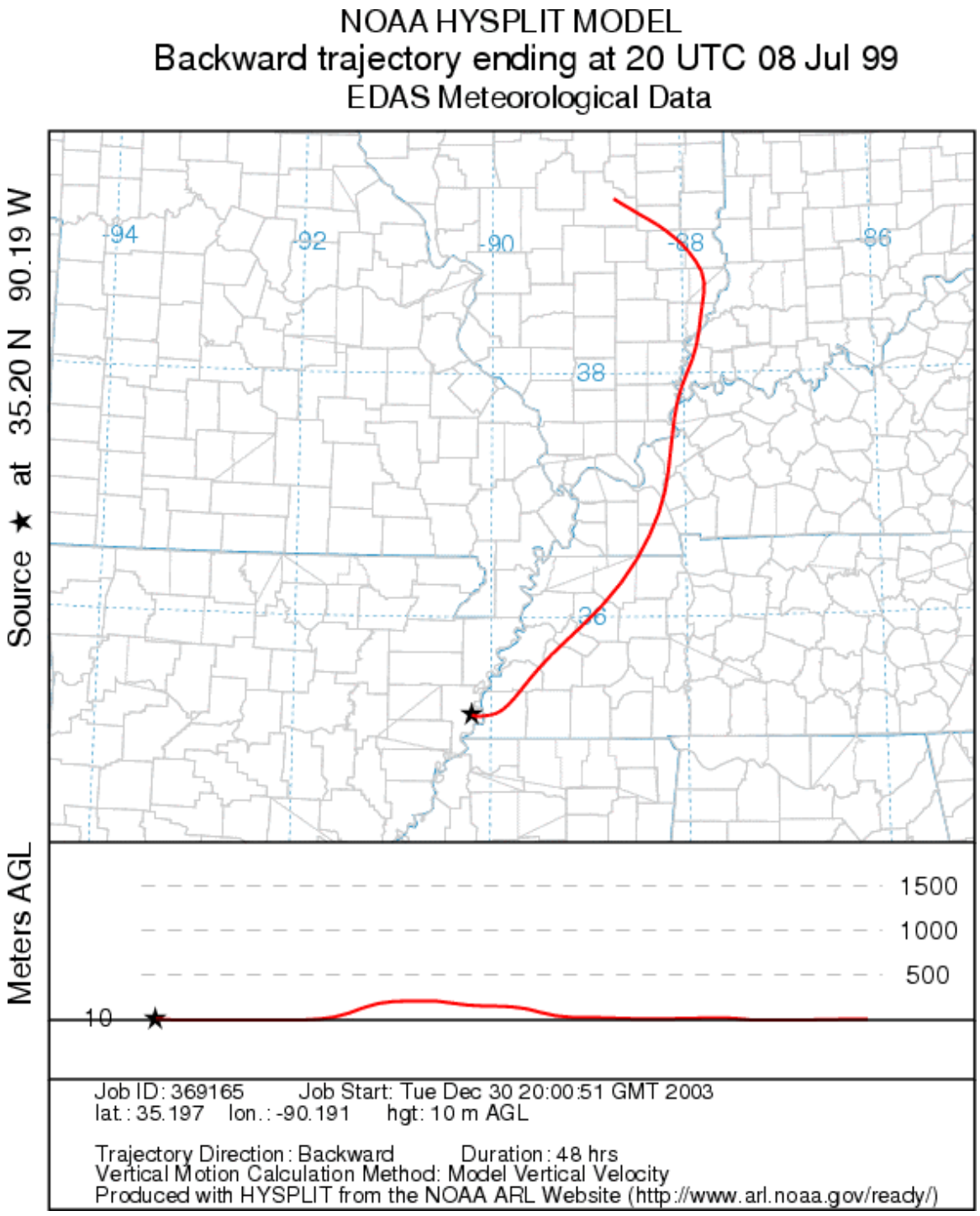
Light southwesterly winds originating in southeastern Arkansas and flowing through eastern Arkansas before arriving at the Marion ozone monitor.

Marion, Arkansas Monitor 48-Hour Back Trajectory for the Period Ending August 22, 1998
Maximum 8-Hour Average – 90 ppb – 2nd Max



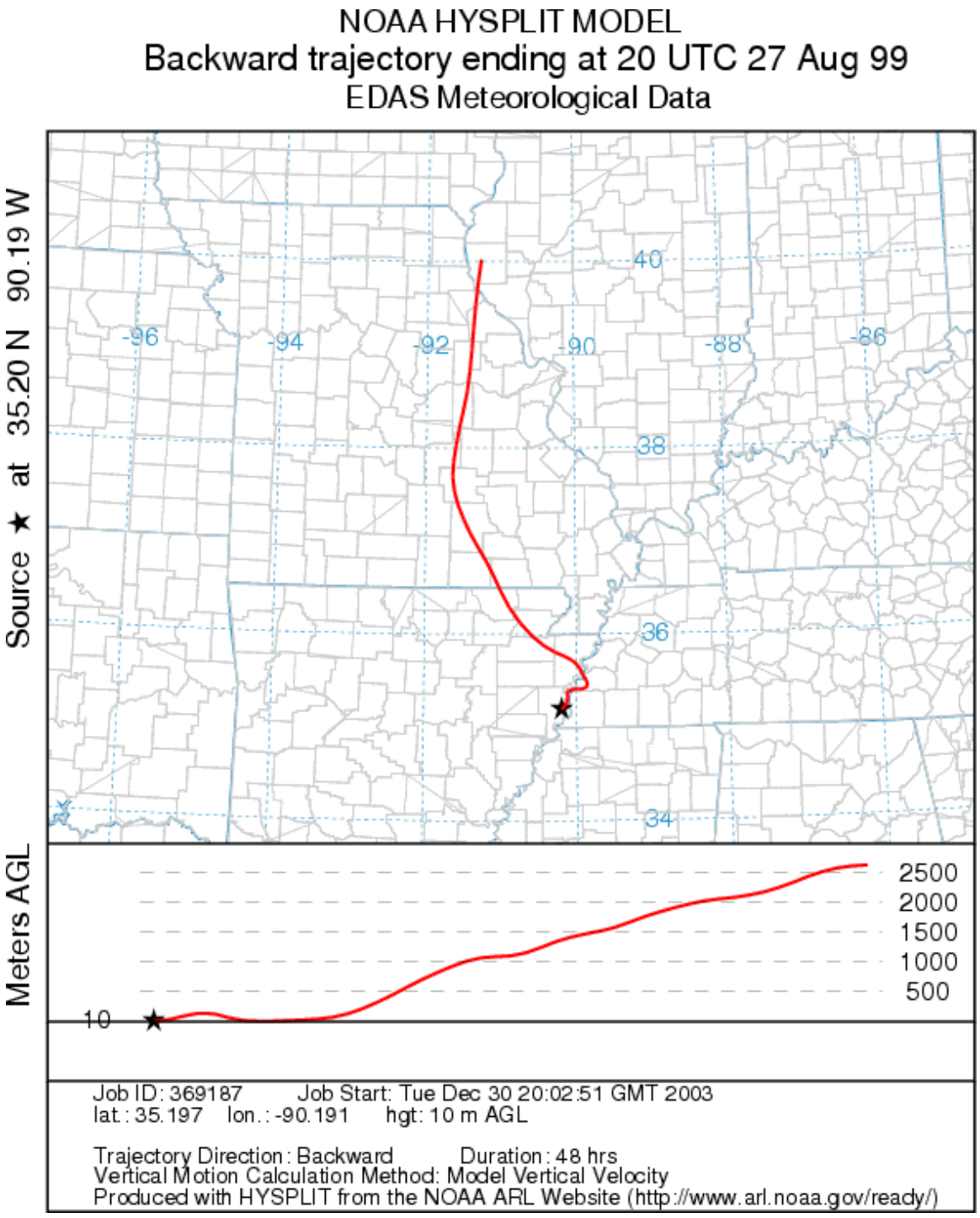
Light southeasterly transport winds originating in northern Alabama and flowing through northern Mississippi before arriving at the Marion ozone monitor.

Marion, Arkansas Monitor 48-Hour Back Trajectory for the Period Ending July 8, 1999
Maximum 8-Hour Average – 104 ppb – 1st Max



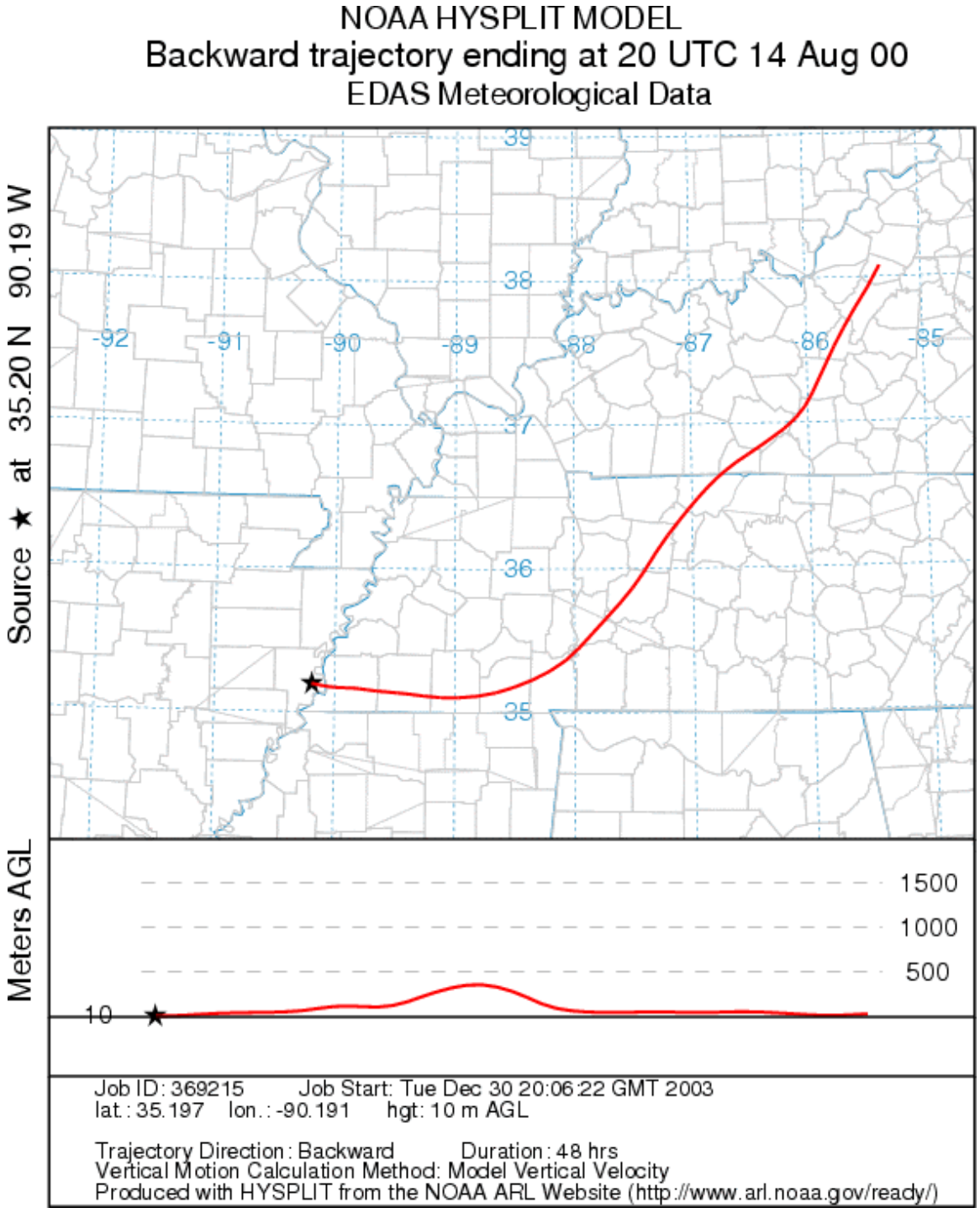
Moderate northerly transport winds originating in central Illinois and flowing through western Kentucky and western Tennessee before arriving at the Marion ozone monitor.

Marion, Arkansas Monitor 48-Hour Back Trajectory for the Period Ending August 27, 1999
Maximum 8-Hour Average – 99 ppb – 2nd Max



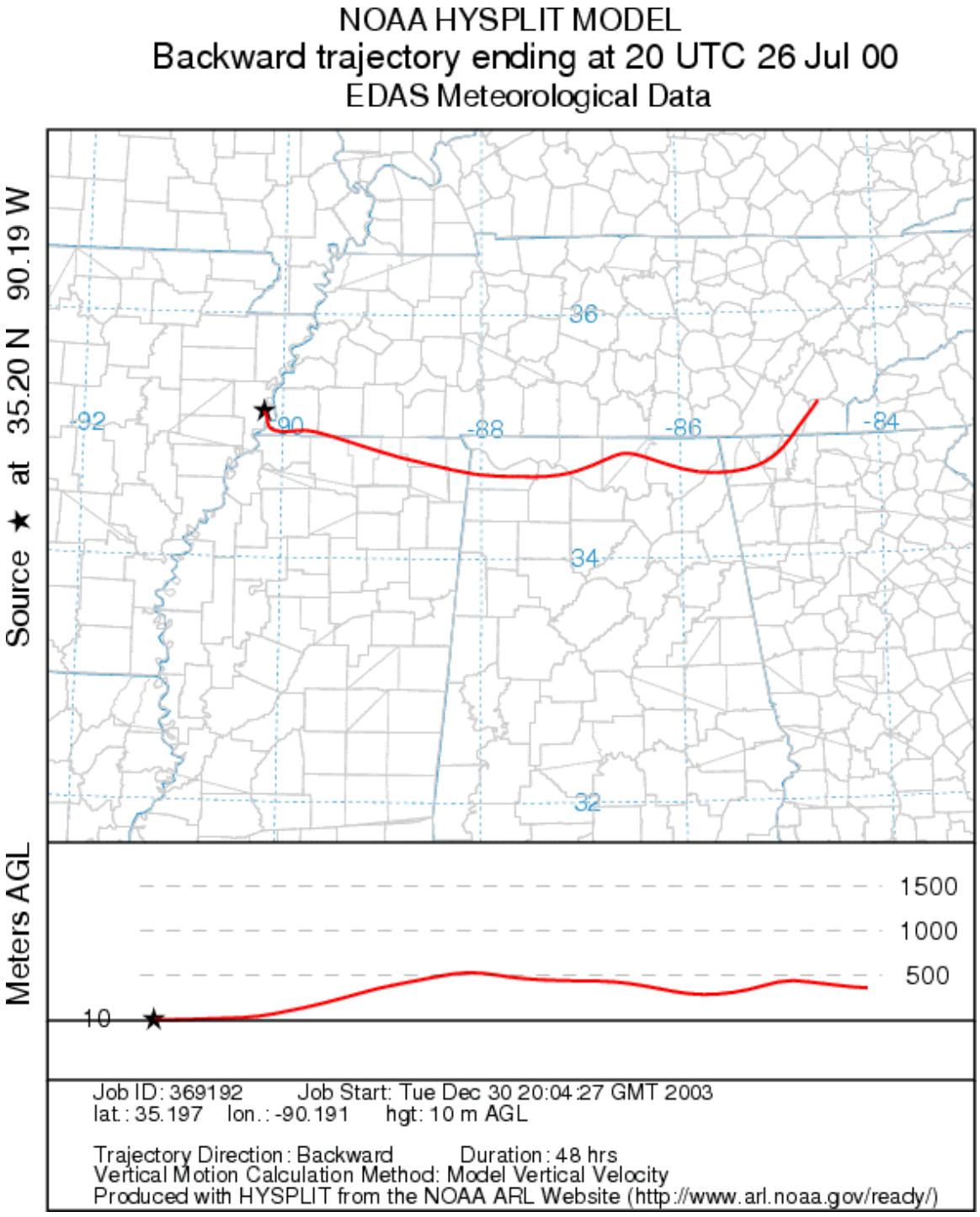
Moderate northerly transport winds originating in eastern Missouri and flowing though northeastern Arkansas before becoming light and variable near the Marion ozone monitor.

Marion, Arkansas Monitor 48-Hour Back Trajectory for the Period Ending August 14, 2000
Maximum 8-Hour Average – 96 ppb – 1st Max



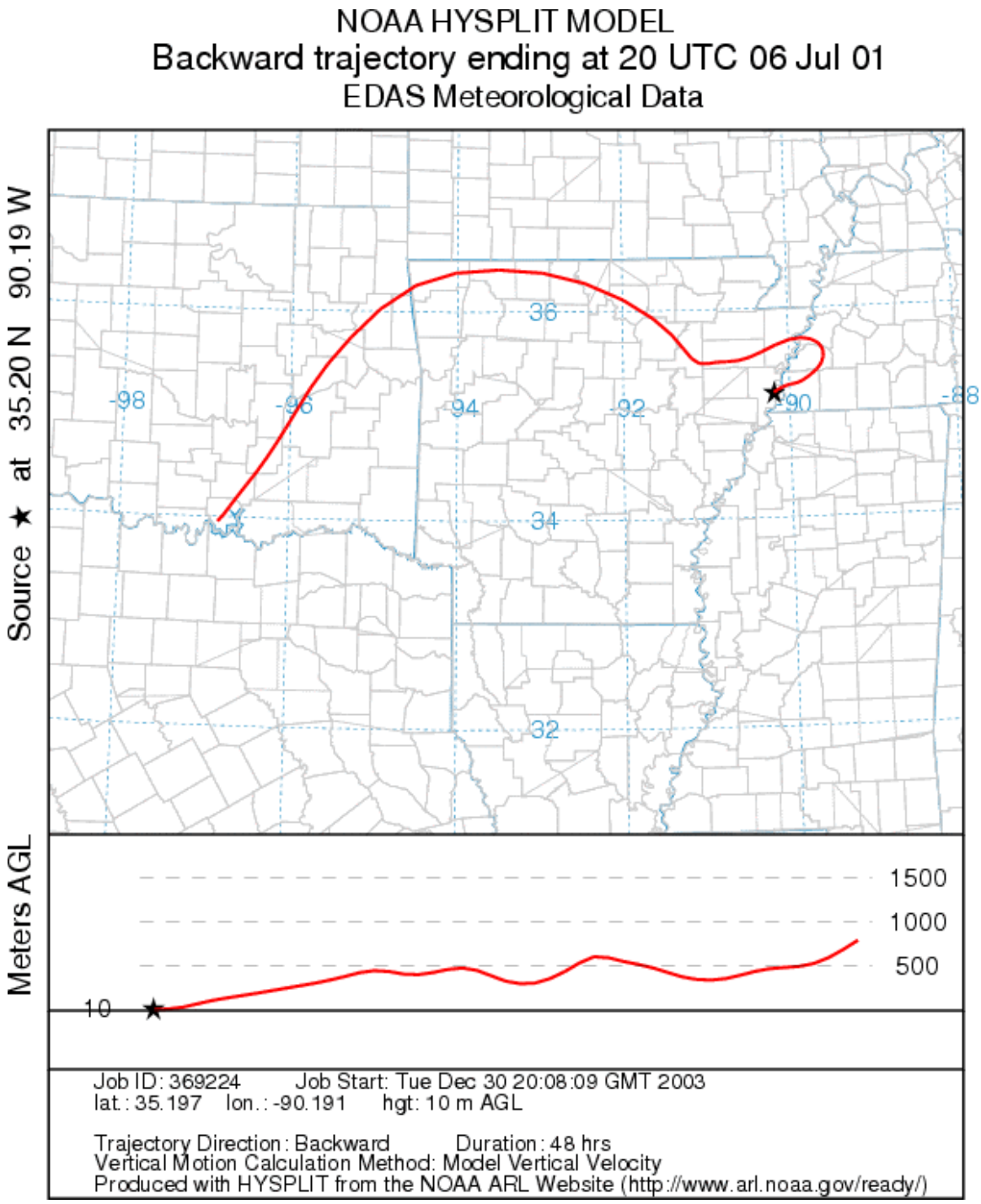
Light northeasterly transport winds originating in central Kentucky and flowing through western Tennessee before arriving at the Marion ozone monitor.

Marion, Arkansas Monitor 48-Hour Back Trajectory for the Period Ending July 26, 2000
Maximum 8-Hour Average – 95 ppb – 2nd Max



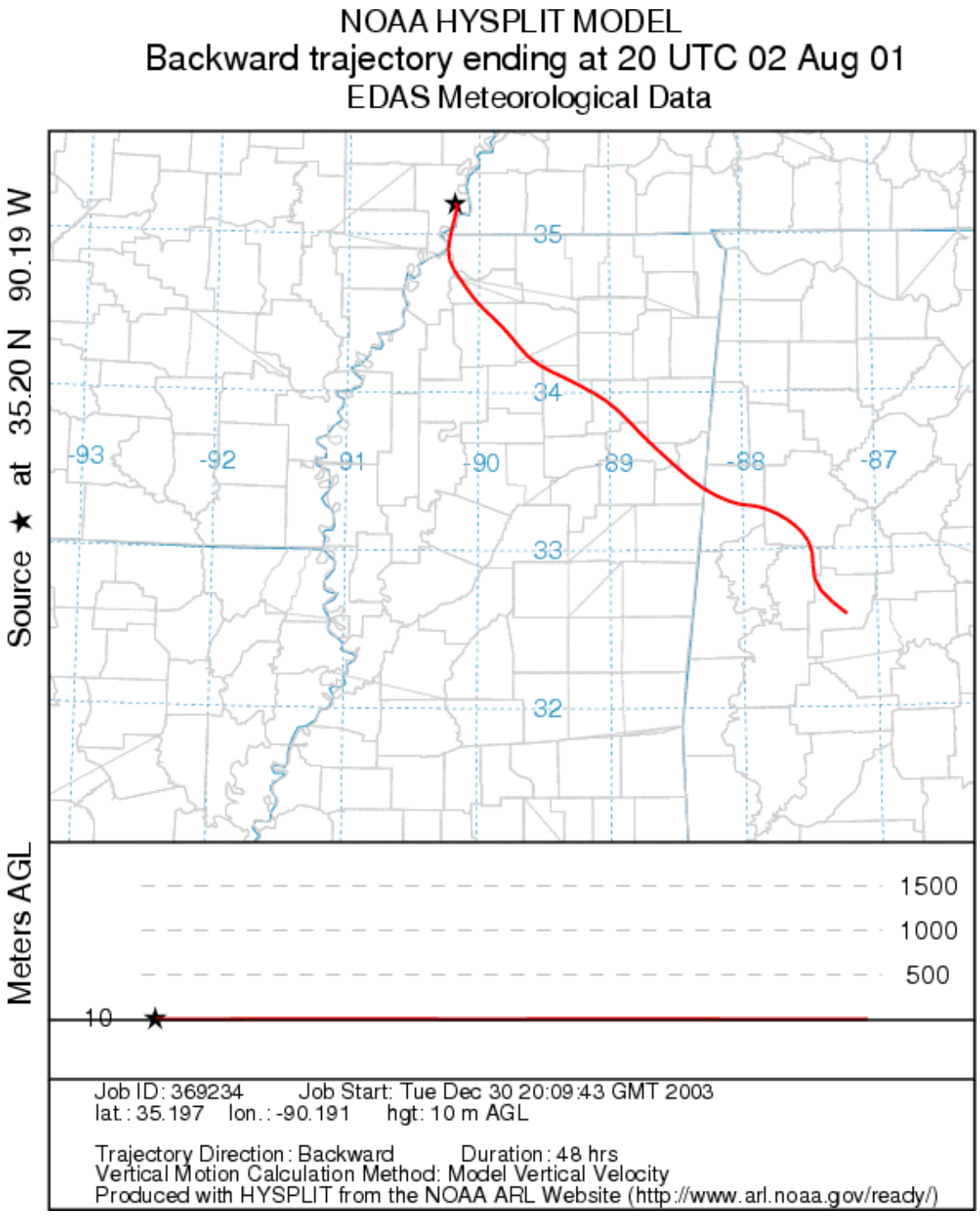
Moderate easterly transport winds originating in southeastern Tennessee and flowing through northwestern Georgia, northern Alabama, and northern Mississippi before arriving at the Marion ozone monitor.

Marion, Arkansas Monitor 48-Hour Back Trajectory for the Period Ending July 6, 2001
Maximum 8-Hour Average – 102 ppb – 1st Max



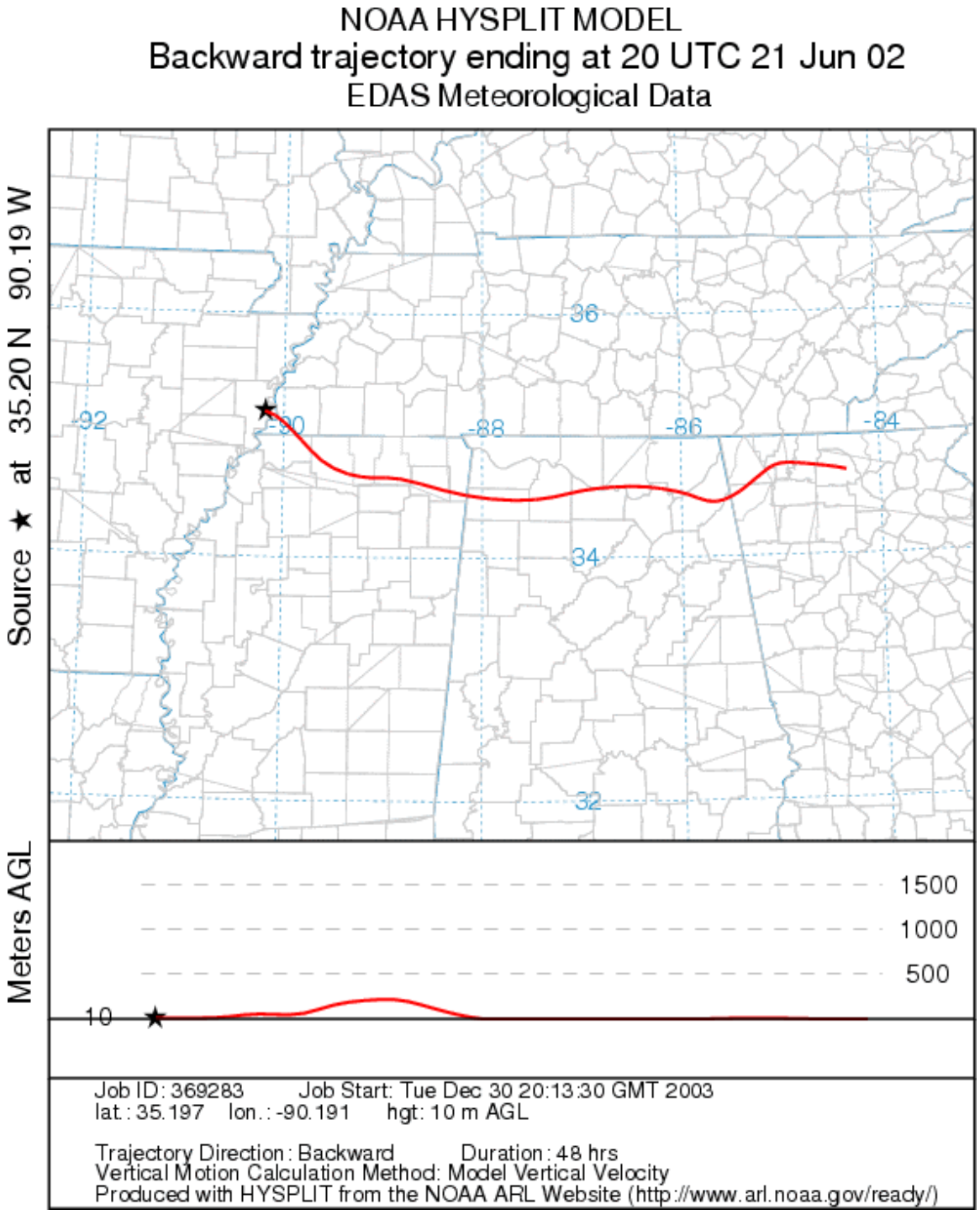
Moderate westerly transport winds originating in southeastern Oklahoma and flowing through northern Arkansas becoming easterly in western Tennessee before arriving at the Marion ozone monitor.

Marion, Arkansas Monitor 48-Hour Back Trajectory for the Period Ending August 2, 2001
Maximum 8-Hour Average – 98 ppb – 2nd Max



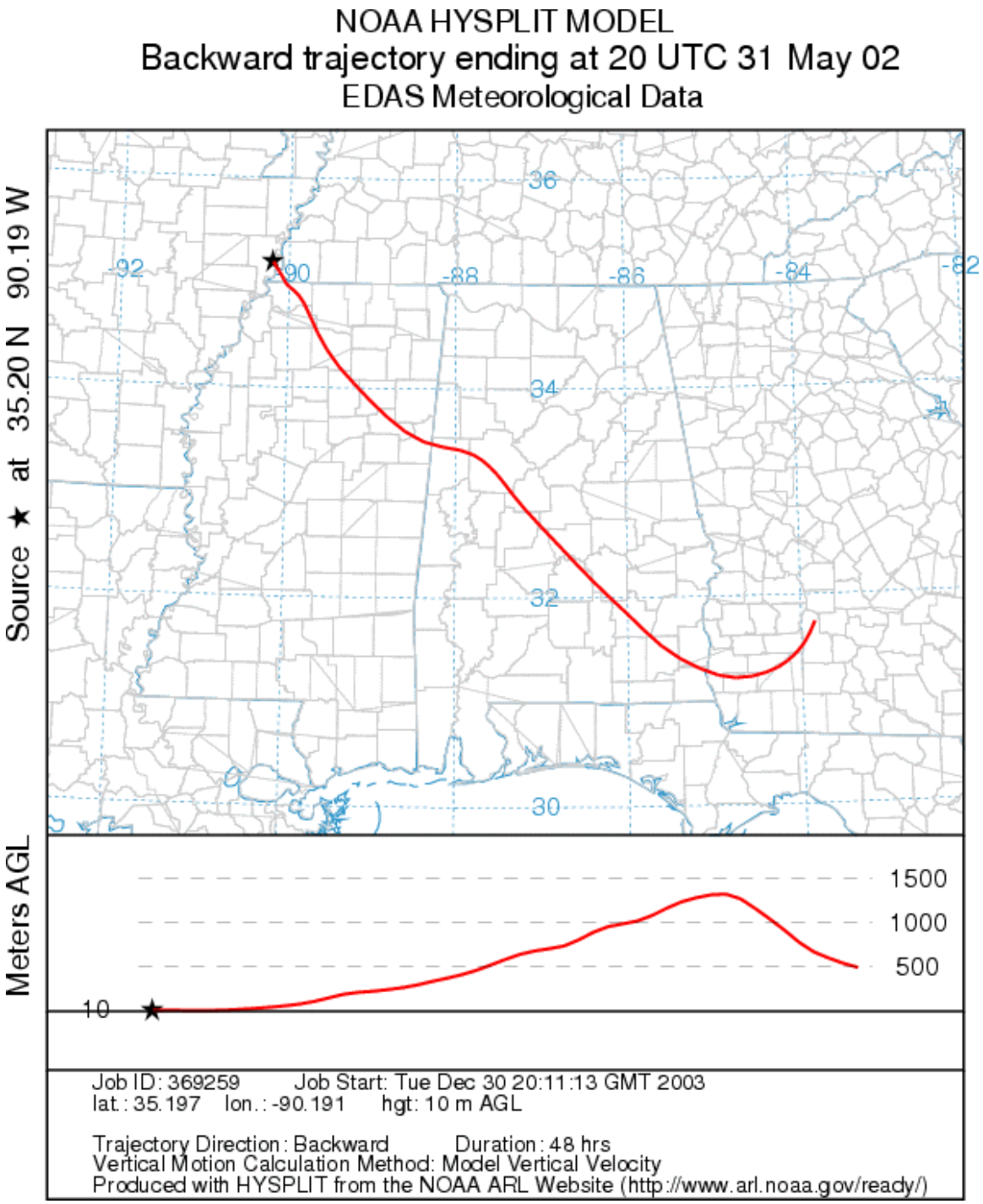
Light southeasterly transport winds originating in west central Alabama and flowing through northern Mississippi before arriving at the Marion ozone monitor.

Marion, Arkansas Monitor 48-Hour Back Trajectory for the Period Ending June 21, 2002
Maximum 8-Hour Average – 107 ppb – 1st Max



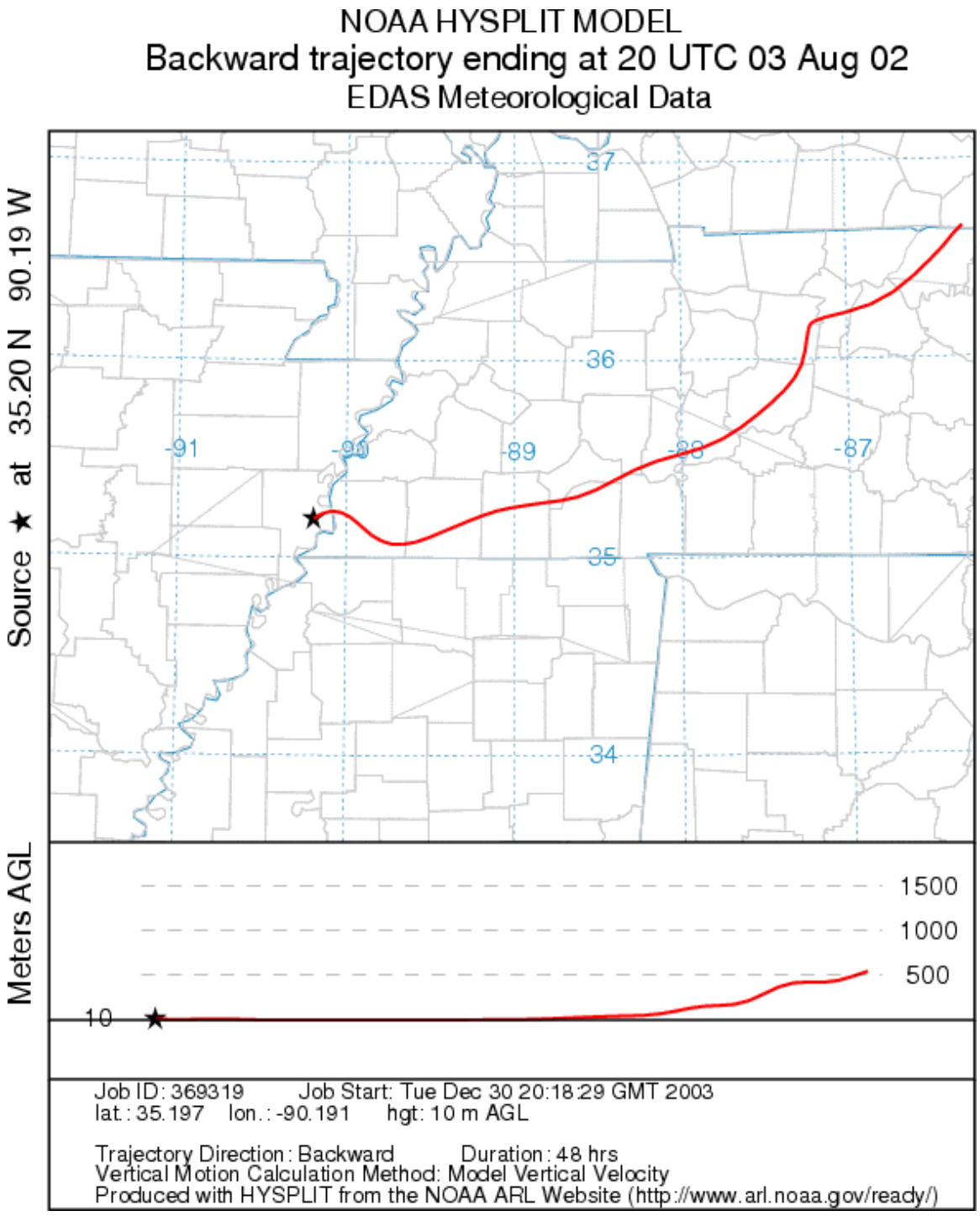
Moderate easterly transport winds originating in northern Georgia and flowing through northern Alabama and northern Mississippi before arriving at the Marion ozone monitor.

Marion, Arkansas Monitor 48-Hour Back Trajectory for the Period Ending May 31, 2002
Maximum 8-Hour Average – 106 ppb – 2nd Max



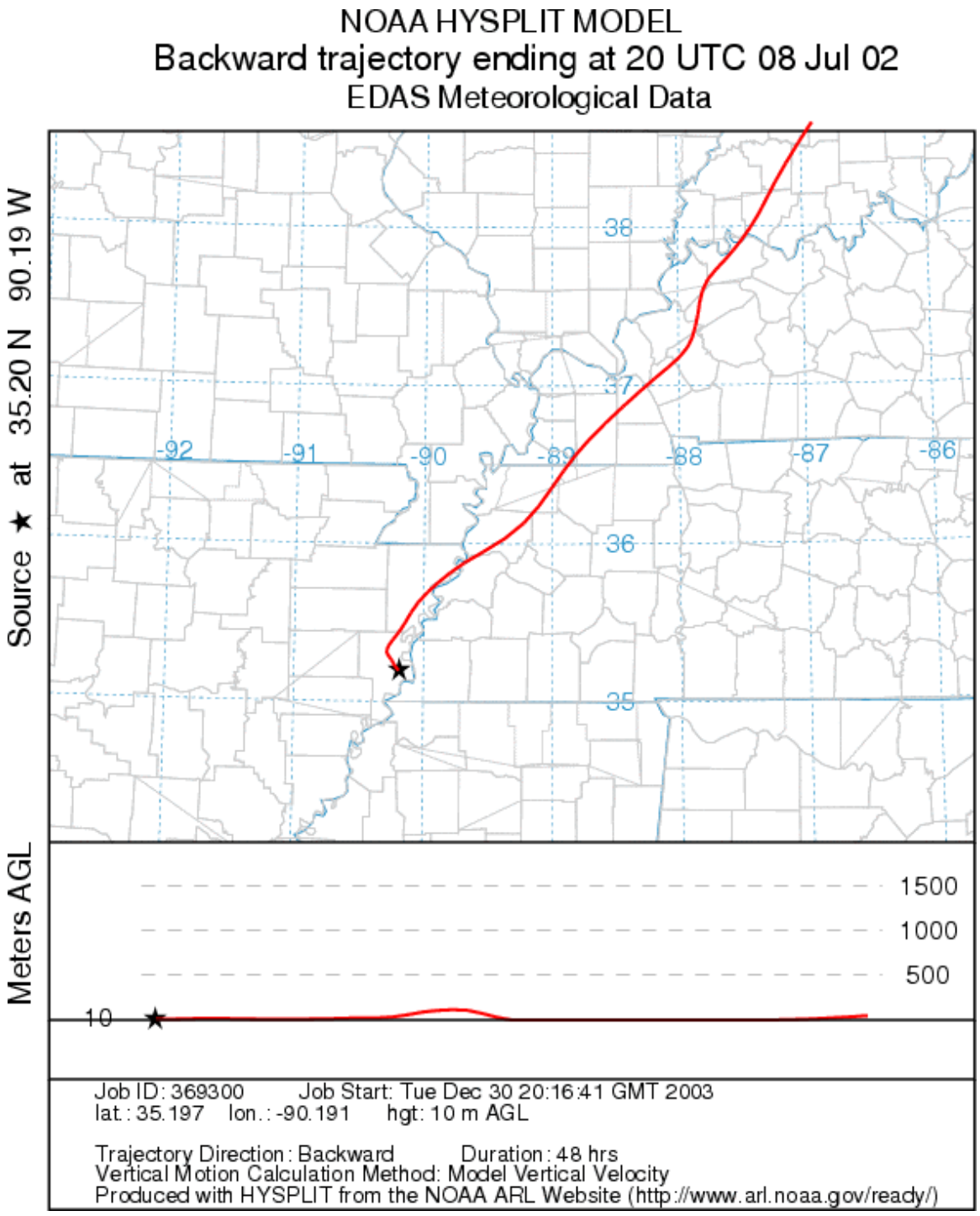
Moderate southeasterly transport winds originating in southwestern Georgia and flowing through central Alabama and northern Mississippi before arriving at the Marion ozone monitor.

Marion, Arkansas Monitor 48-Hour Back Trajectory for the Period Ending August 3, 2002
Maximum 8-Hour Average – 101 ppb – 3rd Max



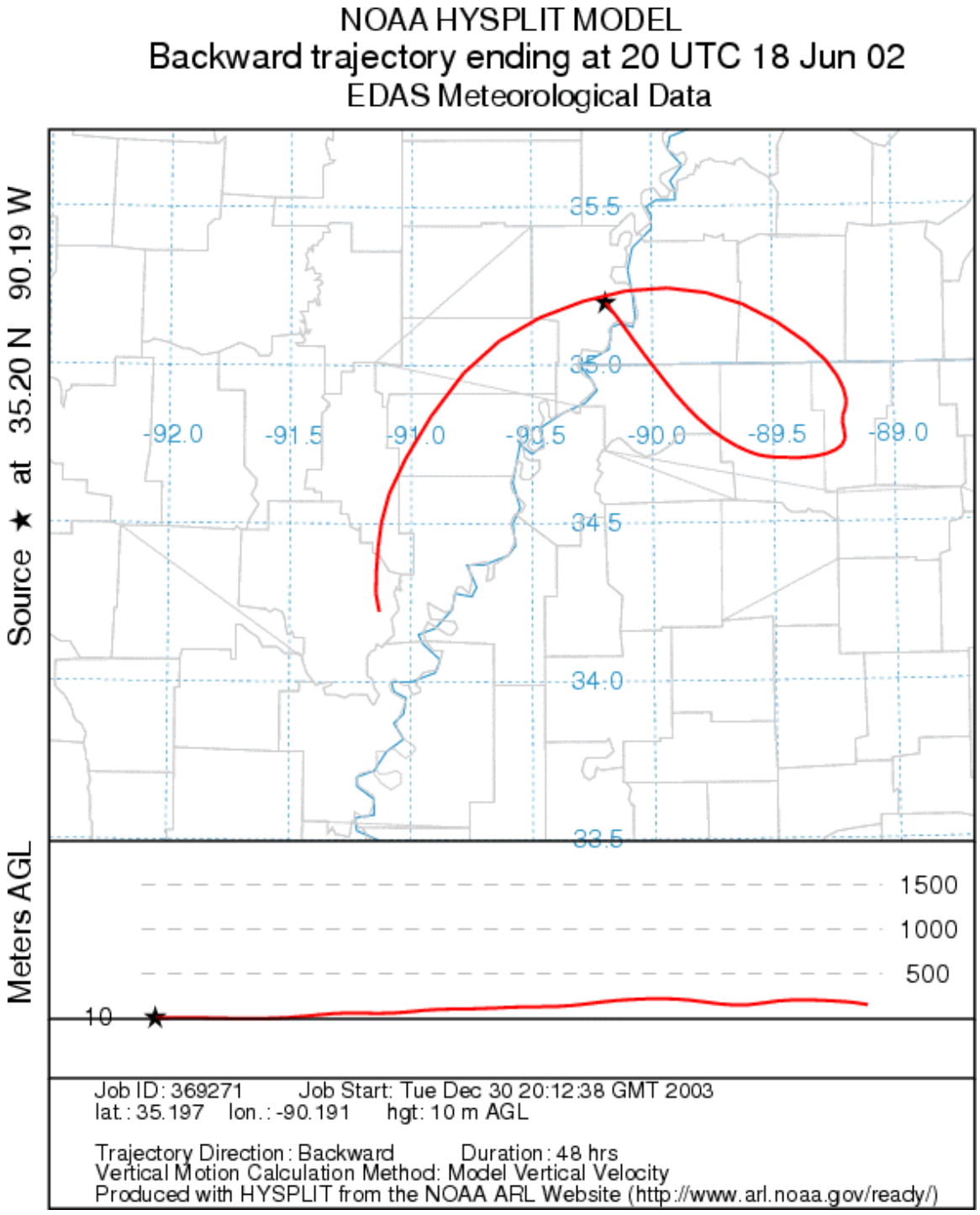
Light northeasterly transport winds flowing through central and southwestern Tennessee before arriving at the Marion ozone monitor.

Marion, Arkansas Monitor 48-Hour Back Trajectory for the Period Ending July 8, 2002
Maximum 8-Hour Average – 100 ppb – 4th Max



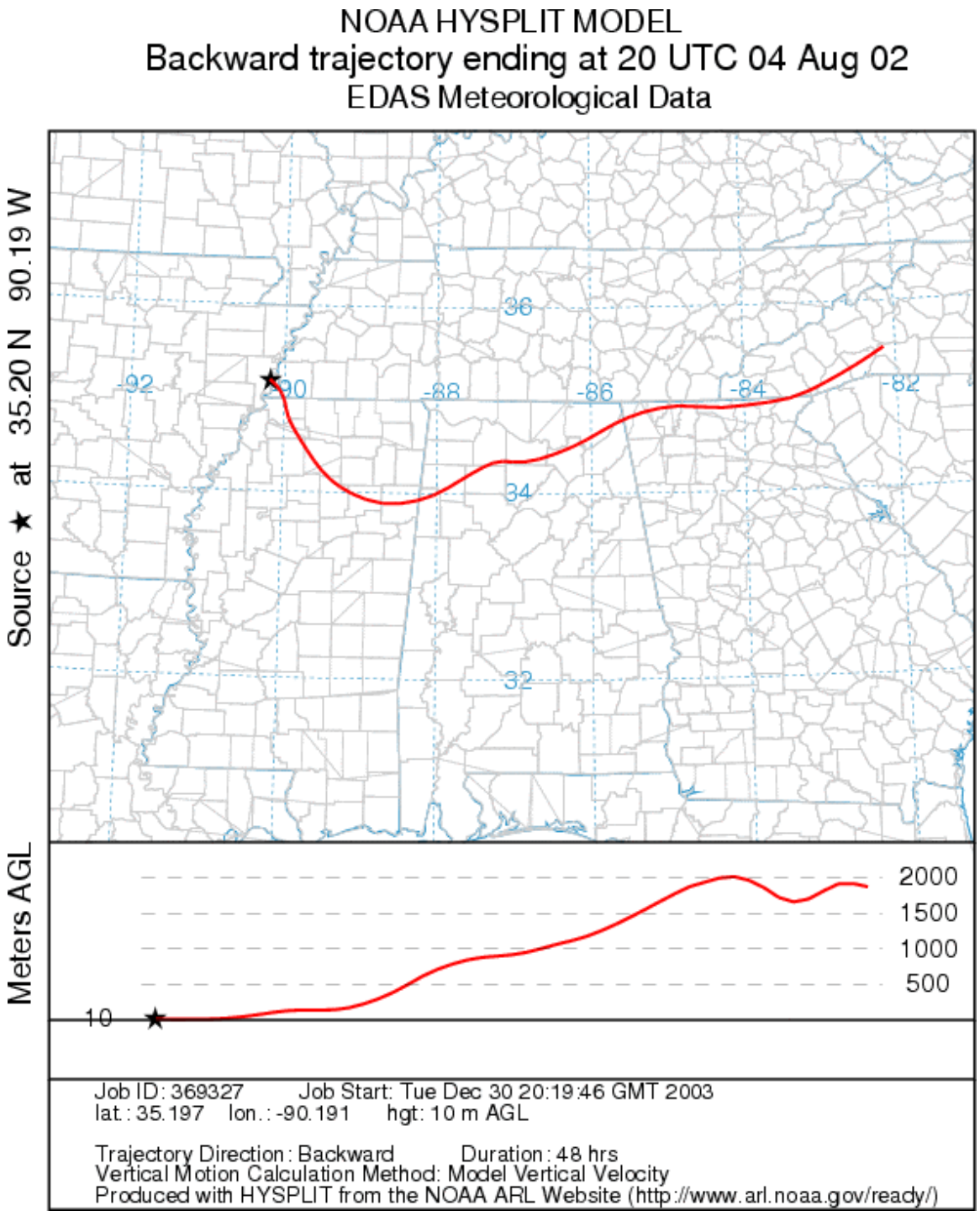
Moderate northeasterly transport winds originating in southwestern Indiana, and flowing through western Kentucky, northwestern Tennessee and northeastern Arkansas before arriving at the Marion ozone monitor.

Marion, Arkansas Monitor 48-Hour Back Trajectory for the Period Ending June 18, 2002
Maximum 8-Hour Average – 97 ppb – 5th Max



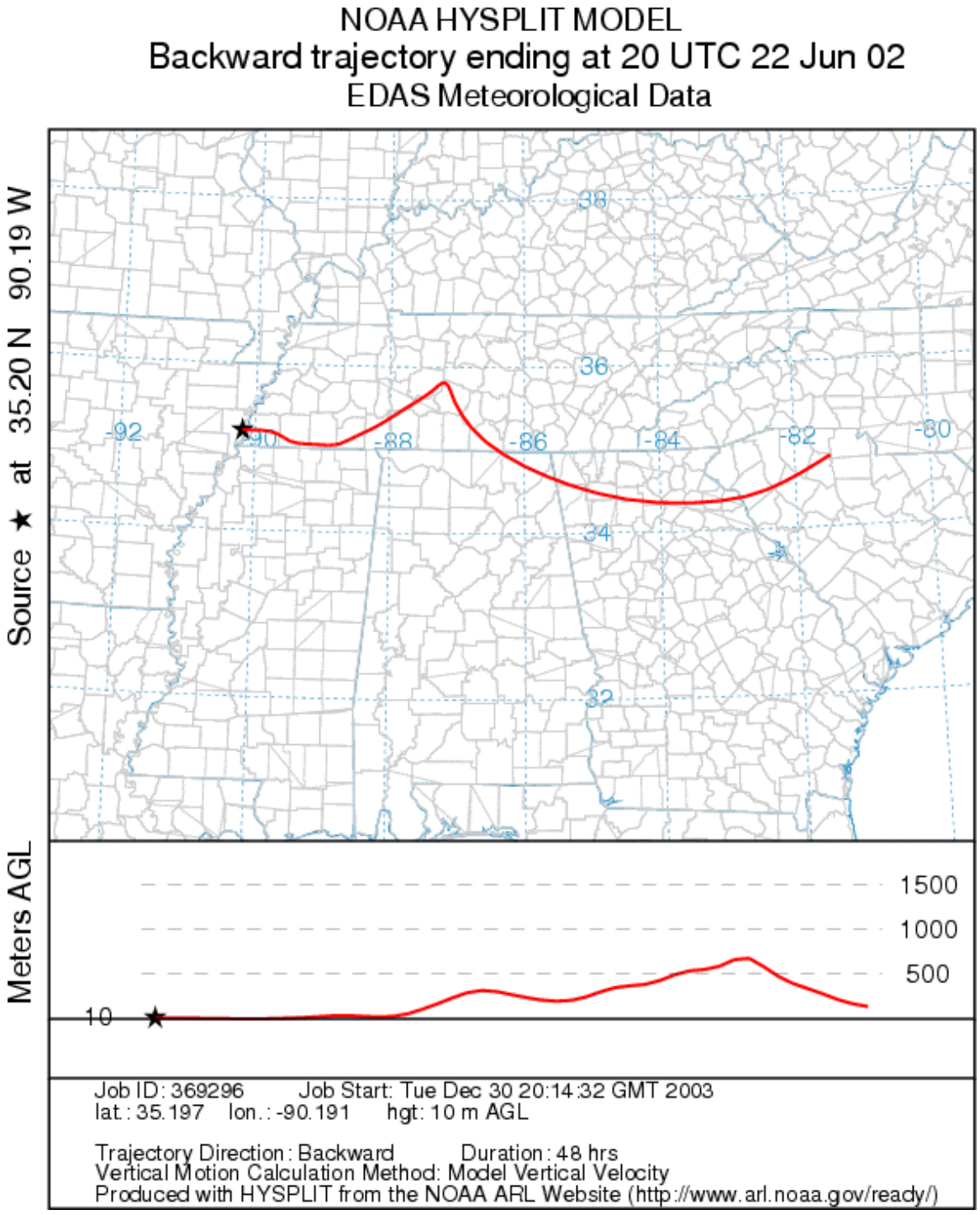
Light and variable transport winds flowing through eastern Arkansas, southwestern Tennessee, and northern Mississippi before arriving at the Marion ozone monitor.

Marion, Arkansas Monitor 48-Hour Back Trajectory for the Period Ending August 4, 2002
Maximum 8-Hour Average – 89 ppb – 6th Max



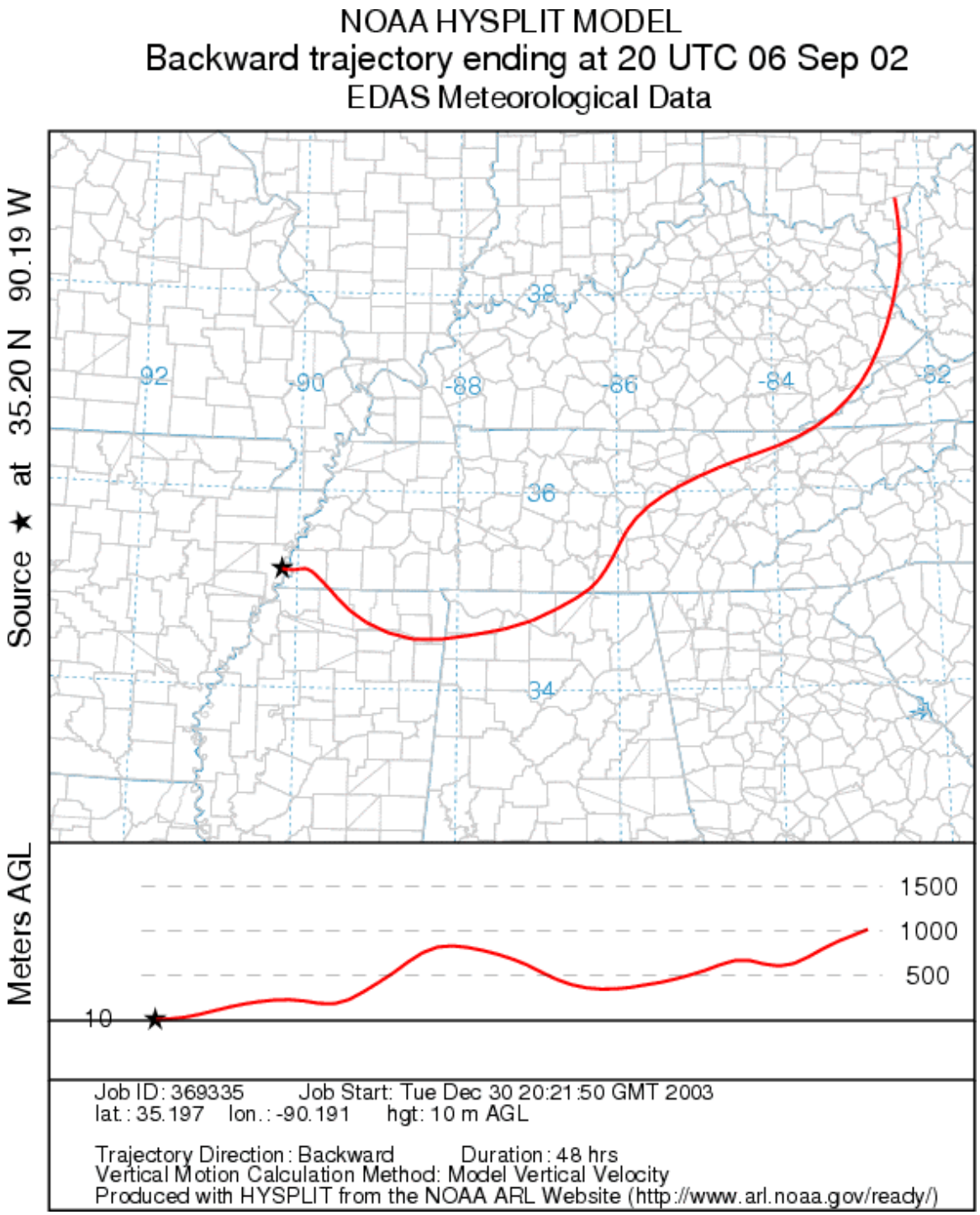
Moderate easterly transport winds originating in southwestern North Carolina and flowing through northern Georgia, northern Alabama, and northern Mississippi becoming southeasterly before arriving at the Marion ozone monitor.

Marion, Arkansas Monitor 48-Hour Back Trajectory for the Period Ending June 22, 2002
Maximum 8-Hour Average – 88 ppb – 7th Max



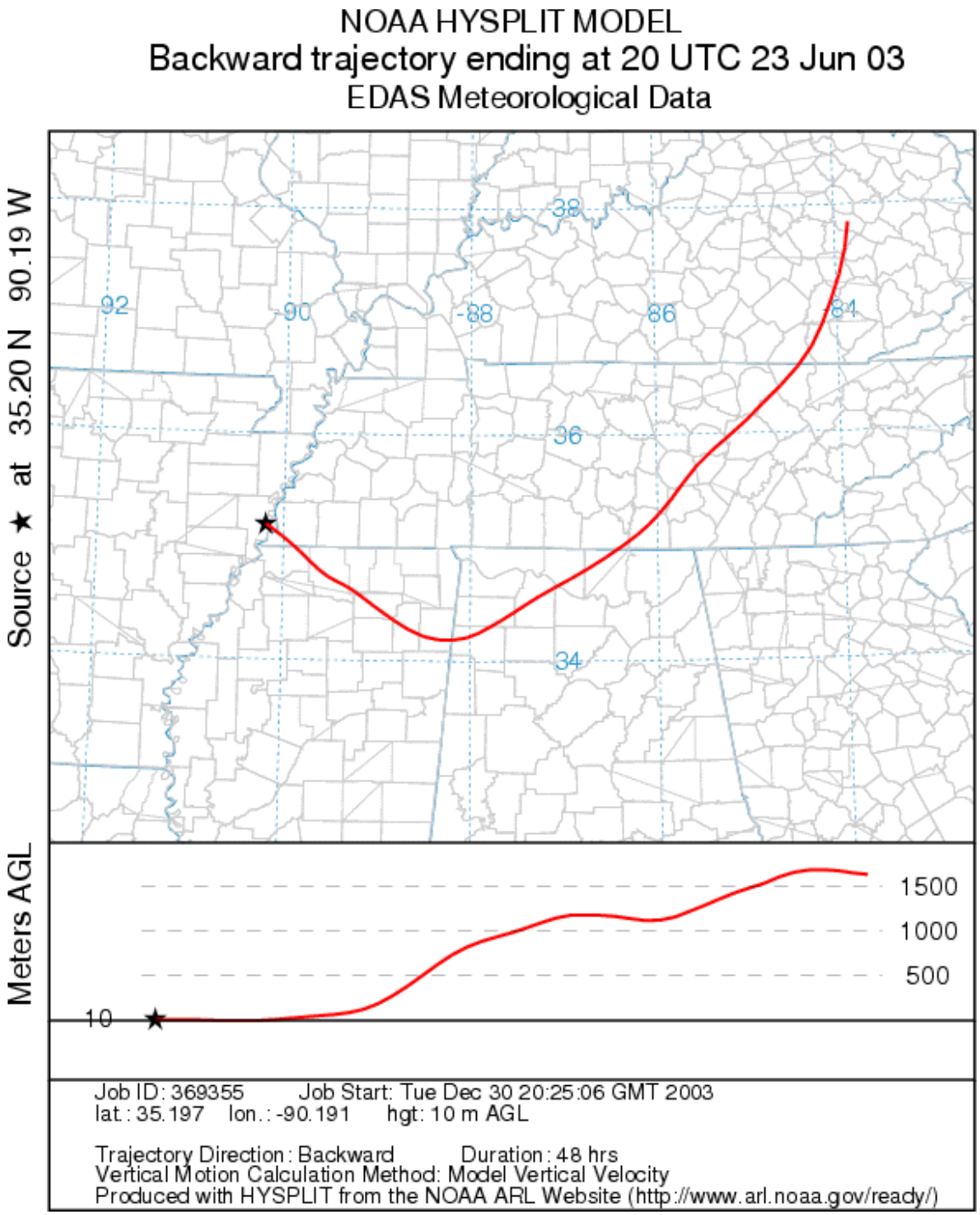
Moderate easterly transport winds originating in northwestern South Carolina and flowing through northern Georgia, northeastern Alabama, and southern Tennessee before arriving at the Marion ozone monitor.

Marion, Arkansas Monitor 48-Hour Back Trajectory for the Period Ending September 6, 2002
Maximum 8-Hour Average – 87 ppb – 8th Max



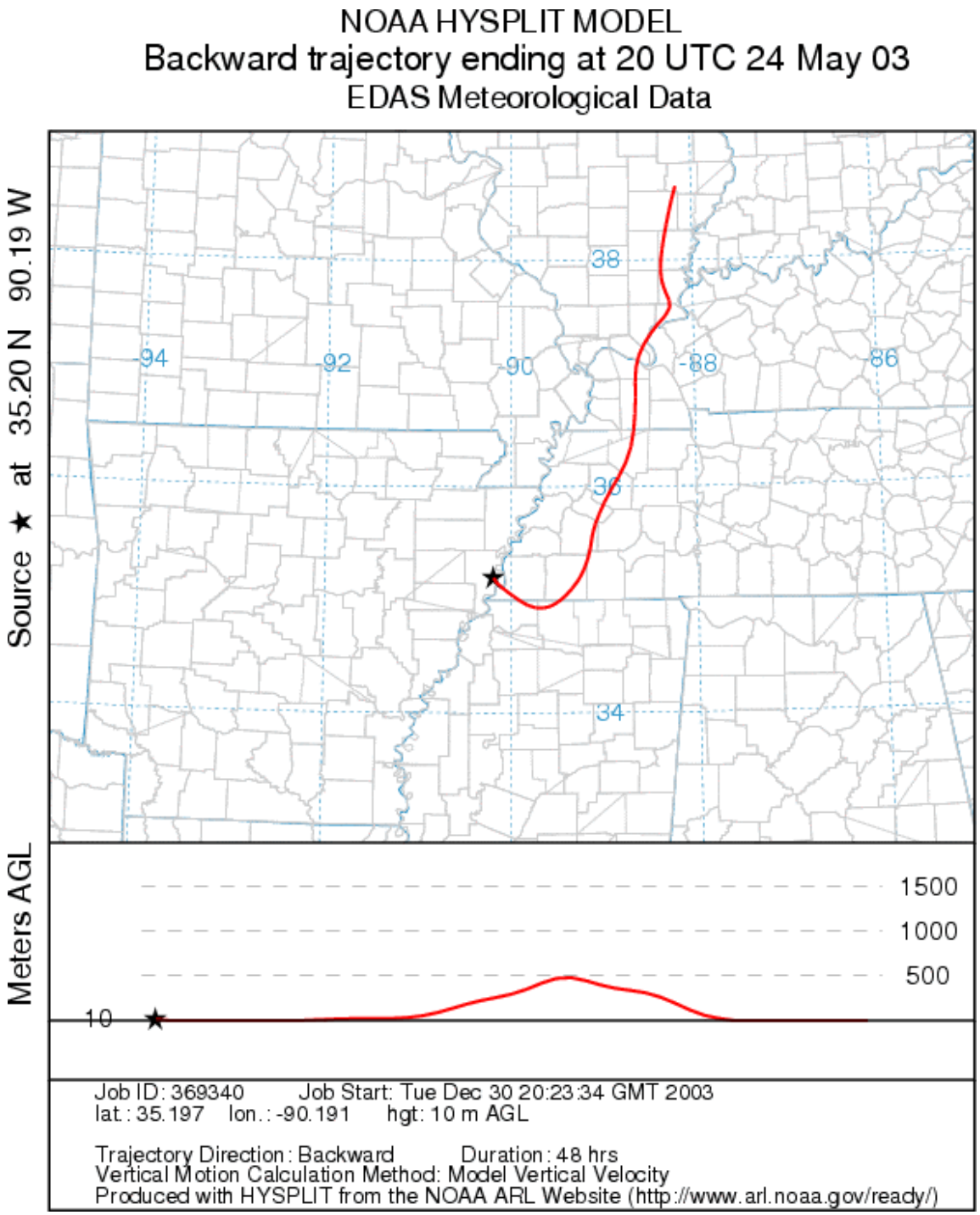
Moderate northeasterly transport winds originating in southern Ohio and flowing through eastern Kentucky, central Tennessee, northern Alabama, and northern Mississippi before becoming southeasterly before arriving at the Marion ozone monitor.

Marion, Arkansas Monitor 48-Hour Back Trajectory for the Period Ending June 23, 2003
Maximum 8-Hour Average – 108 ppb – 1st Max



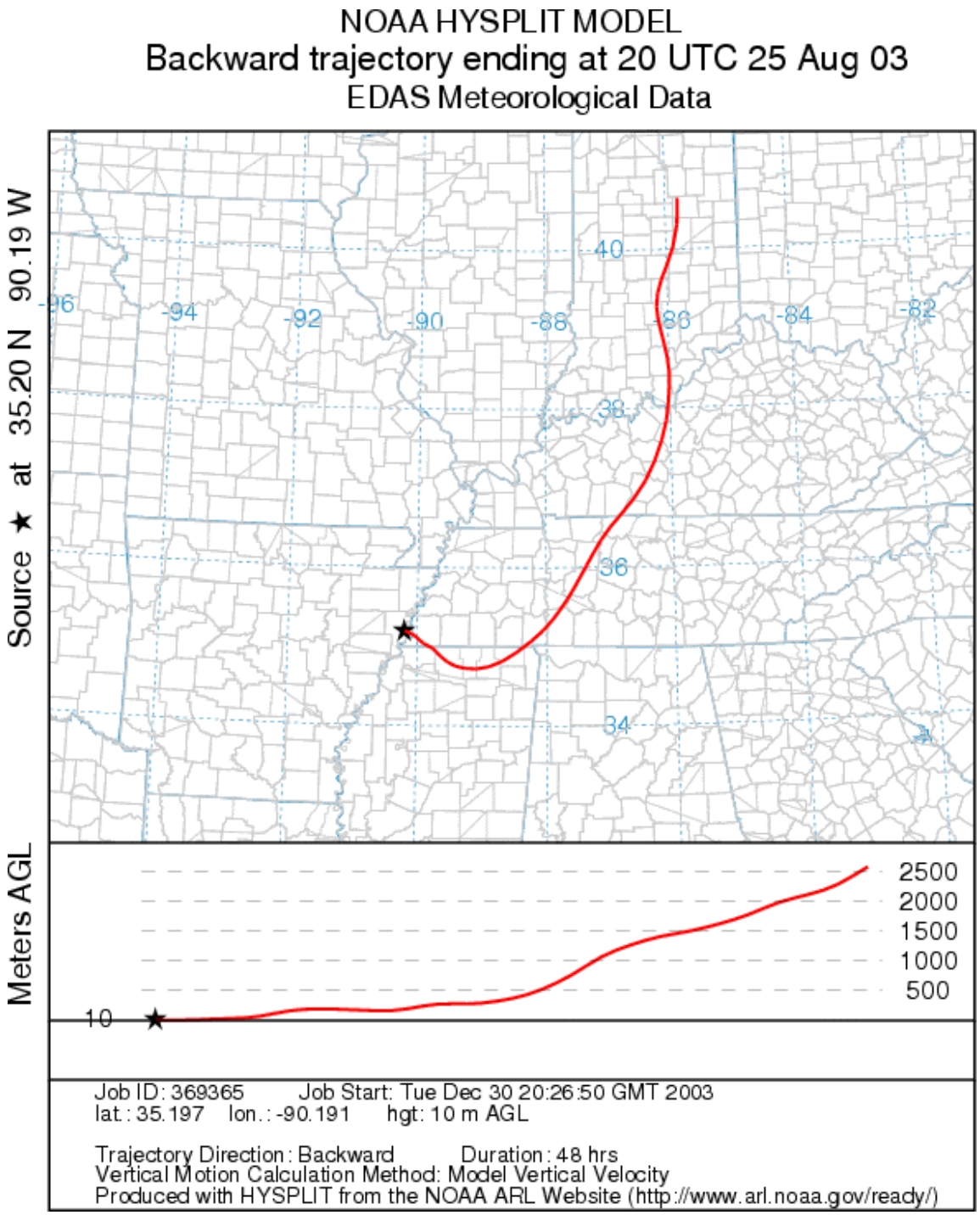
Moderate northeasterly transport winds originating in eastern Kentucky and flowing through central Tennessee, northern Alabama, becoming southeasterly in northern Mississippi before arriving at the Marion ozone monitor.

Marion, Arkansas Monitor 48-Hour Back Trajectory for the Period Ending May 24, 2003
Maximum 8-Hour Average – 96 ppb – 2nd Max



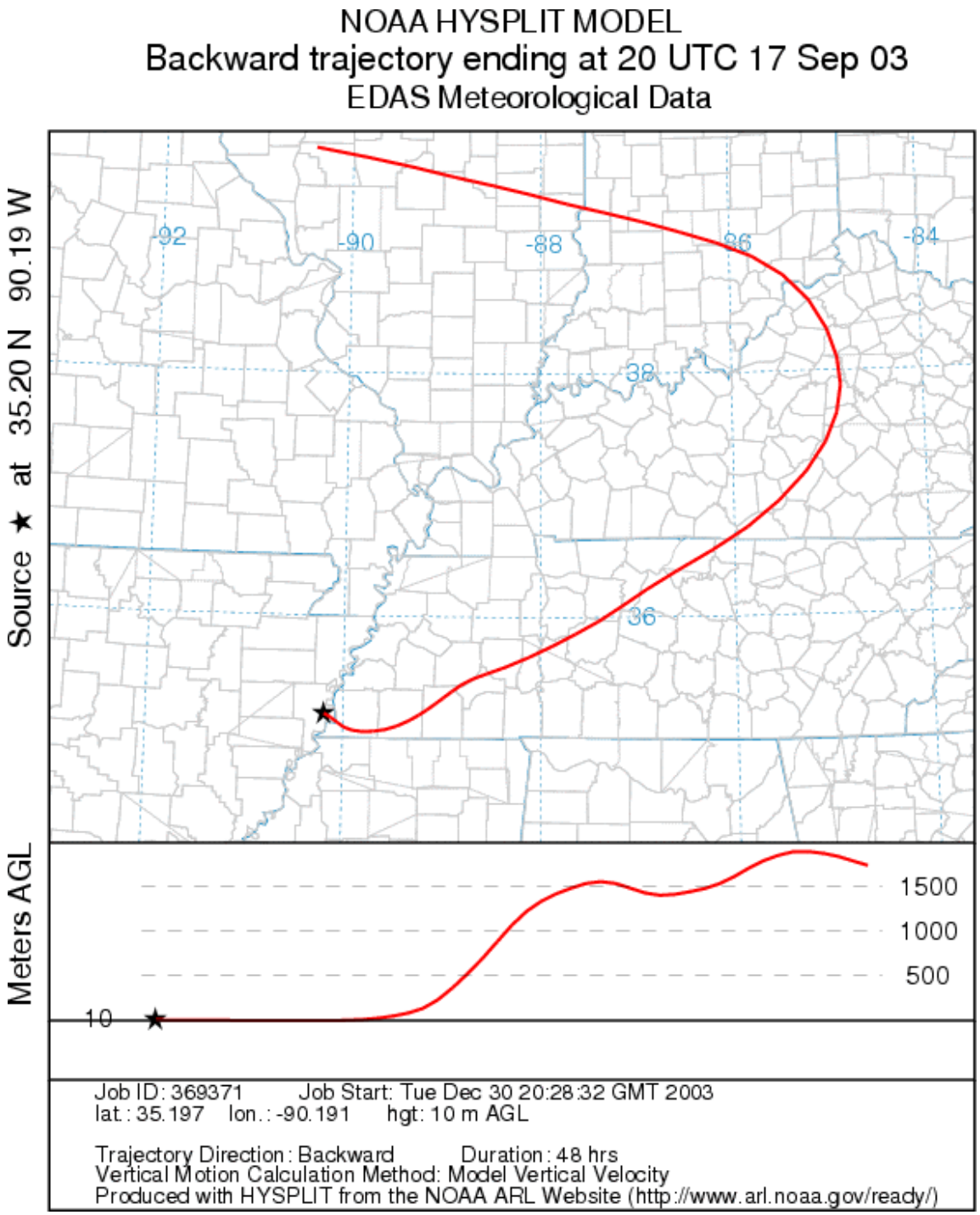
Moderate northerly transport winds originating from southern Illinois and flowing through western Kentucky, western Tennessee becoming easterly before arriving at the Marion ozone monitor.

Marion, Arkansas Monitor 48-Hour Back Trajectory for the Period Ending August 25, 2003
Maximum 8-Hour Average – 92 ppb – 3rd Max



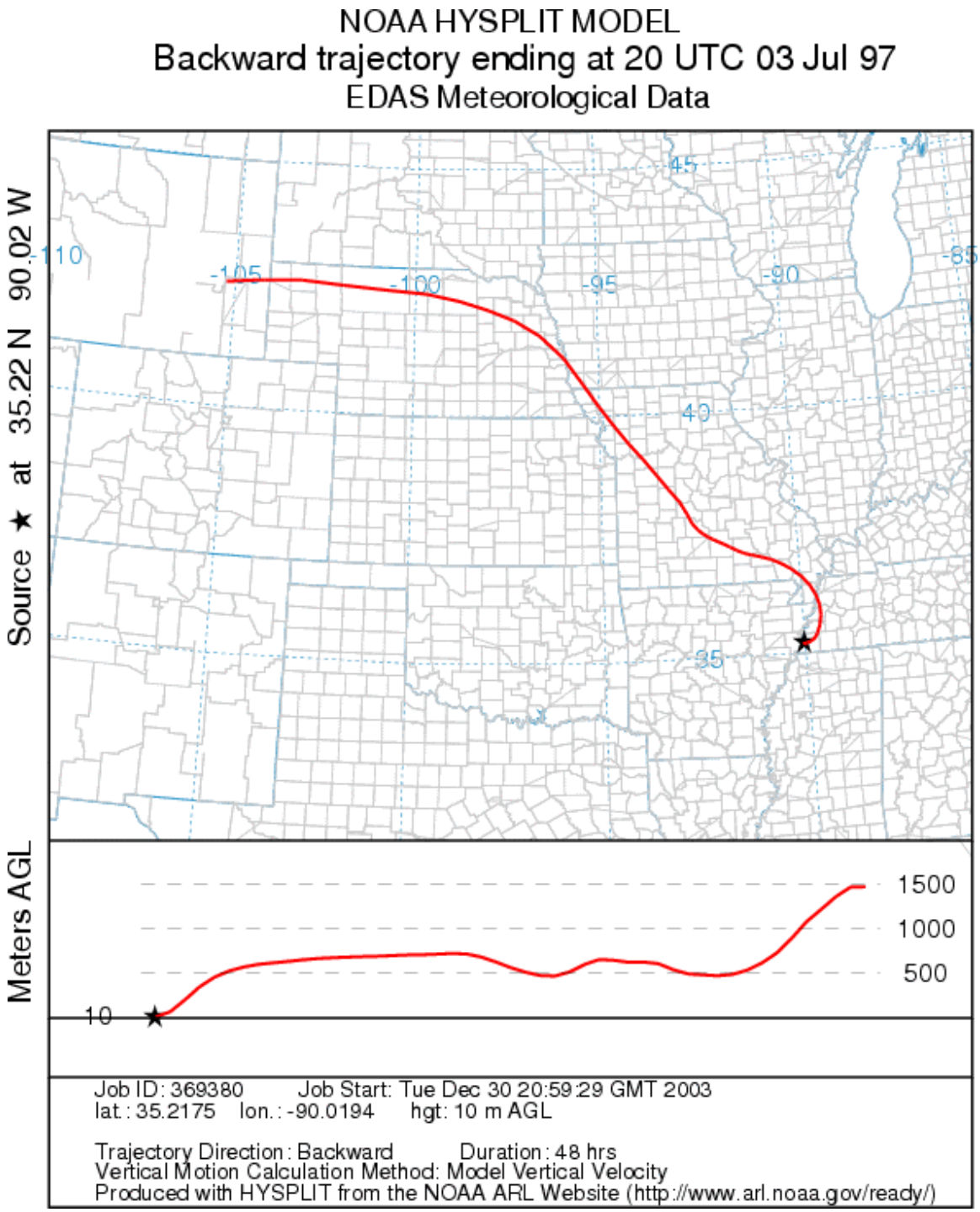
Moderate northerly transport winds originating in central Indiana and flowing through central Kentucky, central Tennessee, and northern Mississippi becoming easterly before arriving at the Marion ozone monitor.

Marion, Arkansas Monitor 48-Hour Back Trajectory for the Period Ending September 17, 2003
Maximum 8-Hour Average – 90 ppb – 4th Max



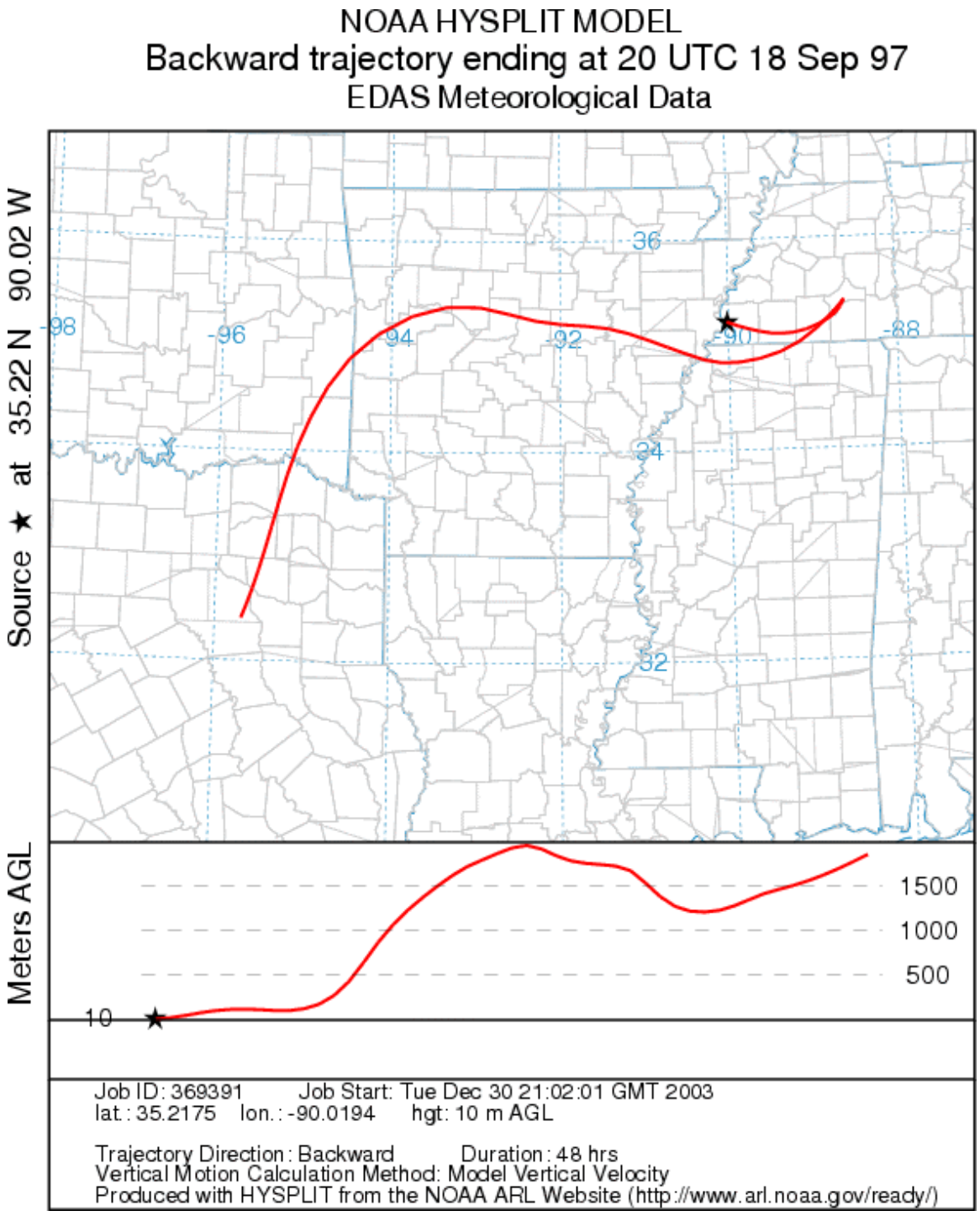
Moderate westerly transport winds originating in west central Illinois and flowing through southern Indiana becoming northerly through central Kentucky becoming northeasterly over central and western Tennessee before arriving at the Marion ozone monitor.

Memphis, Tennessee Monitor 48-Hour Back Trajectory for the Period Ending July 3, 1997
Maximum 8-Hour Average – 107 ppb – 1st Max



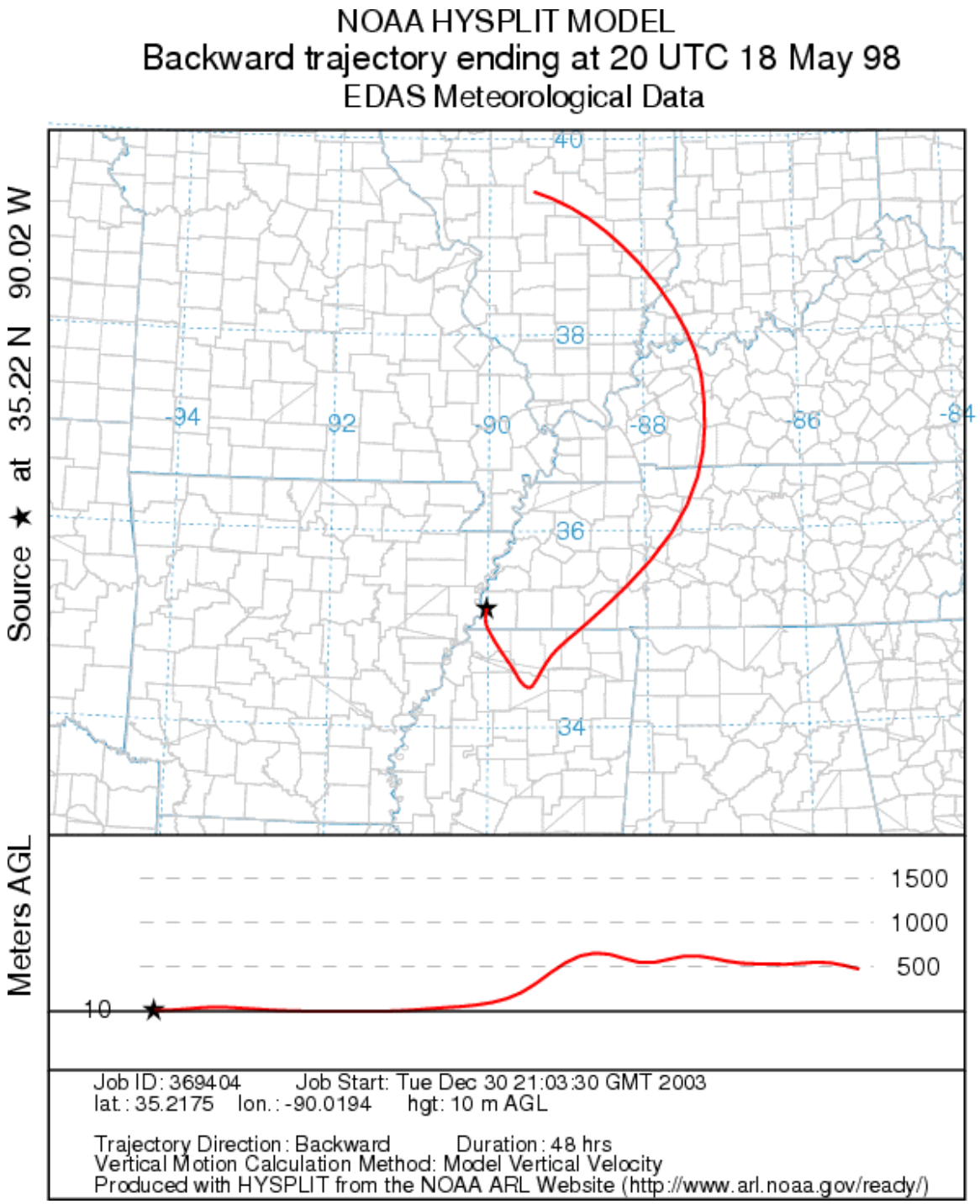
Strong northwesterly transport winds originating in eastern Wyoming and flowing through northern Nebraska, southwestern Iowa, Missouri and western Tennessee before arriving at the Memphis ozone monitor.

Memphis, Tennessee Monitor 48-Hour Back Trajectory for the Period Ending September 18, 1997
Maximum 8-Hour Average – 96 ppb – 2nd Max



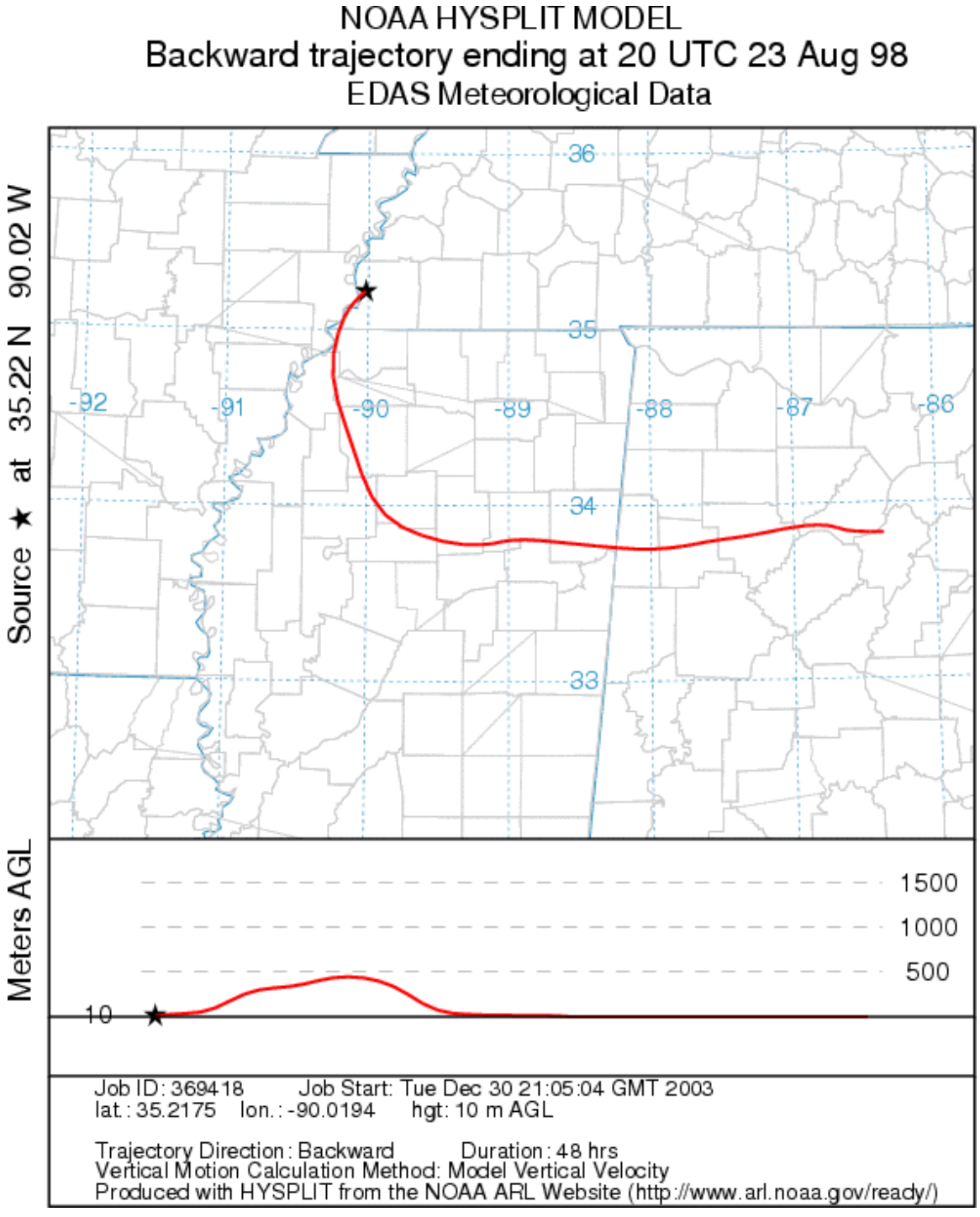
Moderate southerly transport winds originating in northeastern Texas becoming westerly through central Arkansas and northern Mississippi becoming light and variable in southwestern Tennessee before arriving at the Memphis ozone monitor.

Memphis, Tennessee Monitor 48-Hour Back Trajectory for the Period Ending May 18, 1998
Maximum 8-Hour Average – 123 ppb – 1st Max



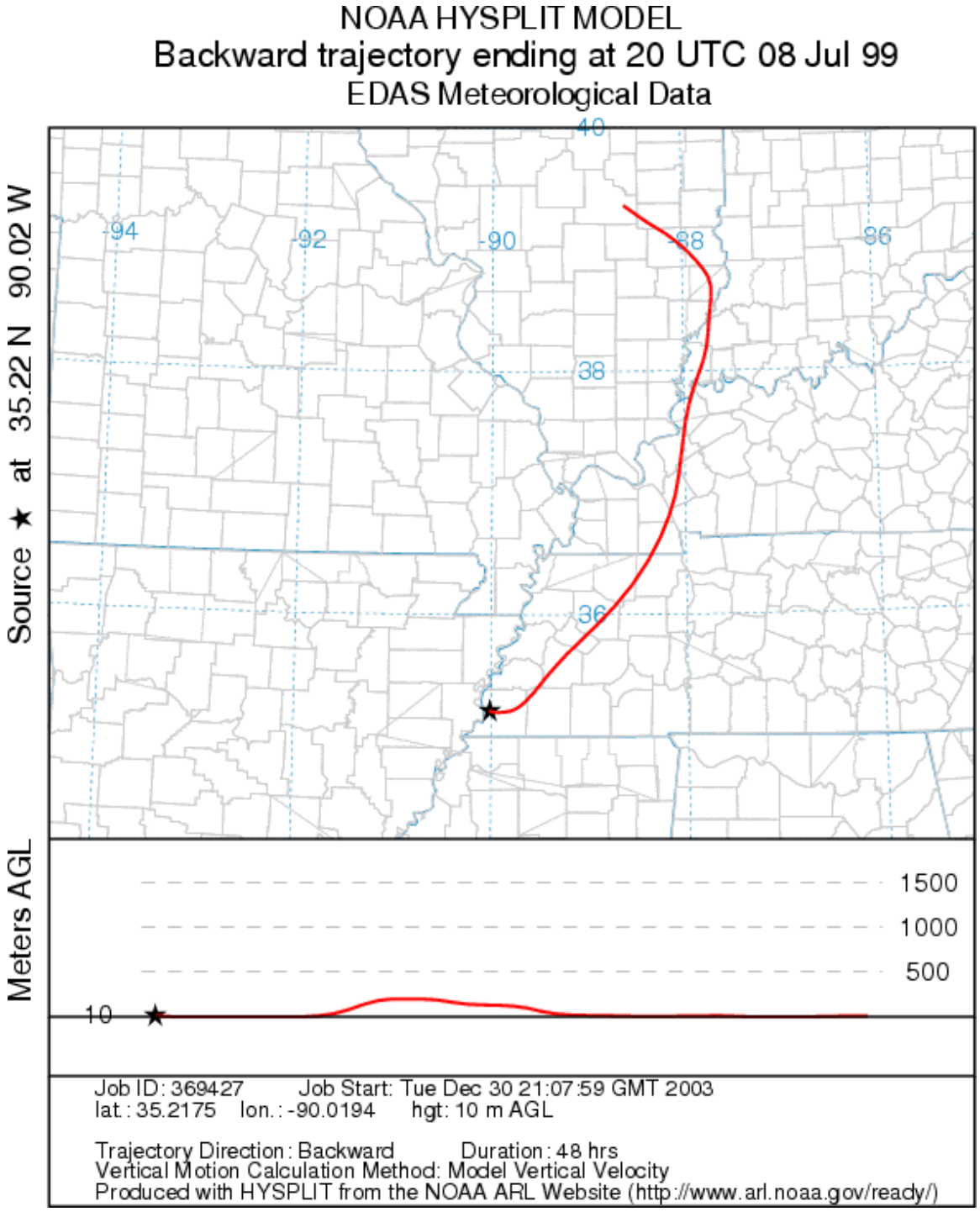
Moderate northerly transport winds originating in southern Illinois and flowing through southwestern Indiana, western Kentucky, western Tennessee, and northern Mississippi becoming southerly before arriving at the Memphis ozone monitor.

Memphis, Tennessee Monitor 48-Hour Back Trajectory for the Period Ending August 23, 1998
Maximum 8-Hour Average – 94 ppb – 2nd Max



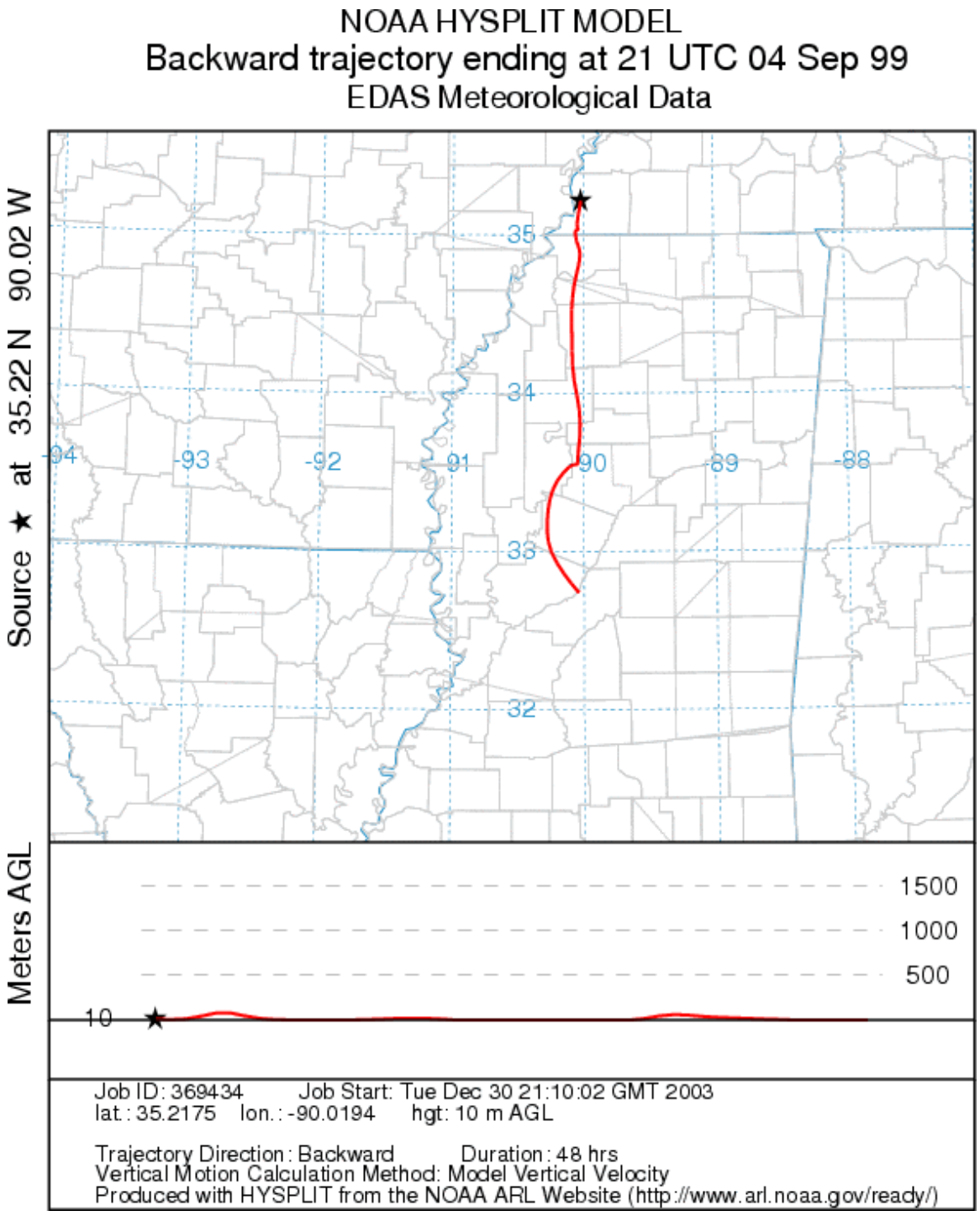
Light easterly transport winds originating in northern Alabama and flowing through northern Mississippi becoming southerly before arriving at the Memphis ozone monitor.

Memphis, Tennessee Monitor 48-Hour Back Trajectory for the Period Ending July 8, 1999
Maximum 8-Hour Average – 110 ppb – 1st Max



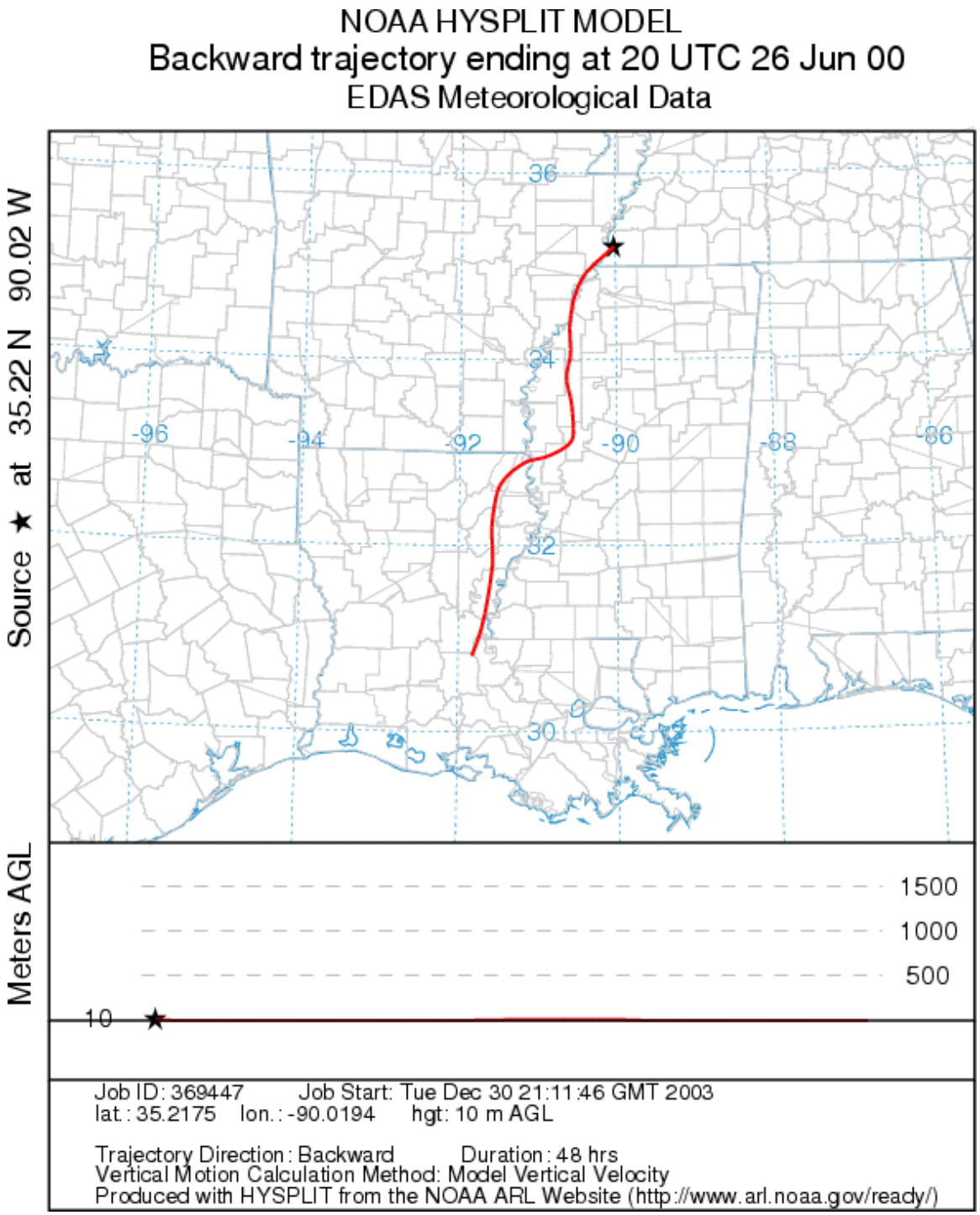
Moderate northerly transport winds originating in eastern Illinois and flowing through southwestern Indiana, western Kentucky, and western Tennessee before arriving at the Memphis ozone monitor.

Memphis, Tennessee Monitor 48-Hour Back Trajectory for the Period Ending September 4, 1999
Maximum 8-Hour Average – 106 ppb – 2nd Max



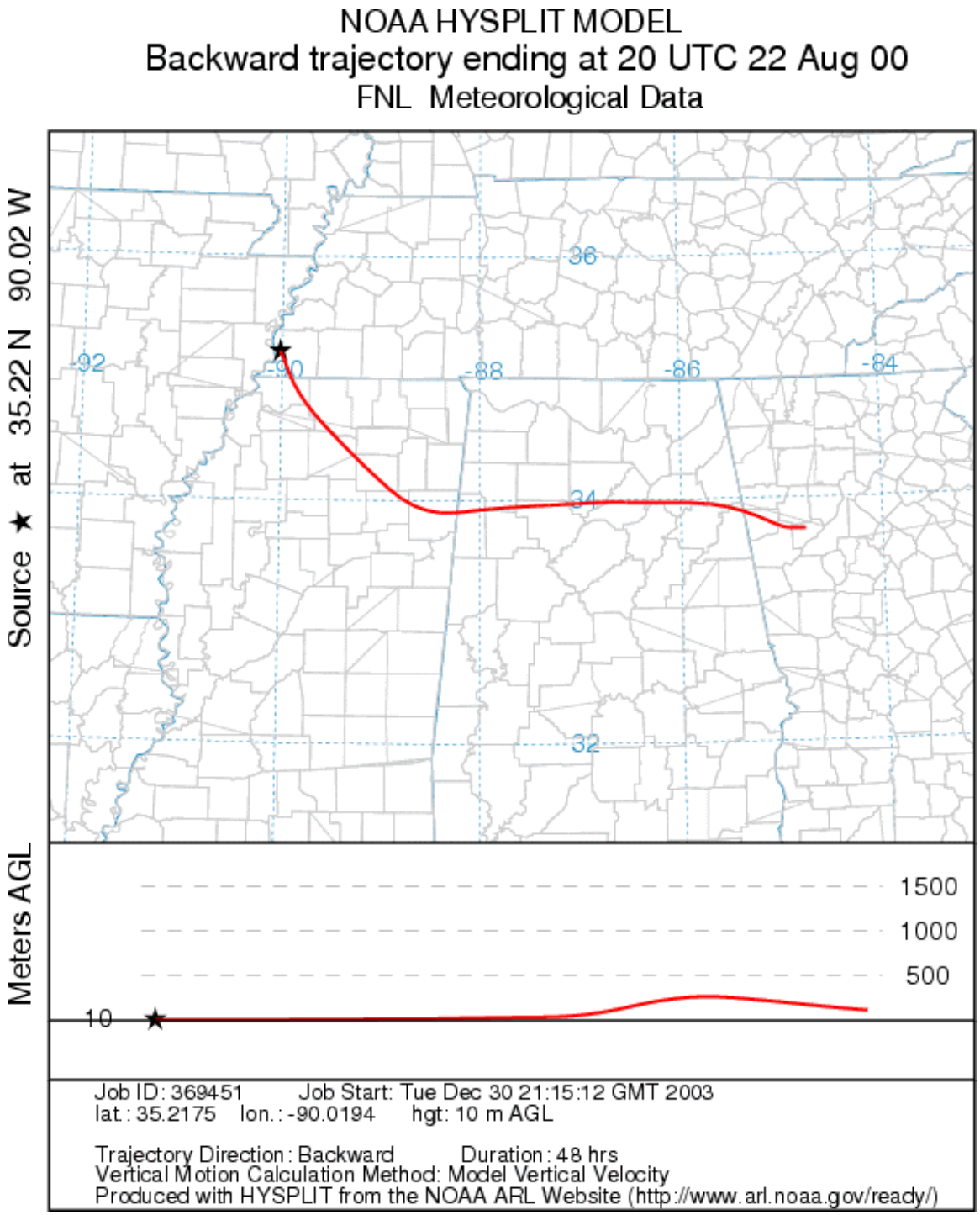
Light southerly transport winds originating in central Mississippi and flowing through western Mississippi before arriving at the Memphis ozone monitor.

Memphis, Tennessee Monitor 48-Hour Back Trajectory for the Period Ending June 26, 2000
Maximum 8-Hour Average – 106 ppb – 1st Max



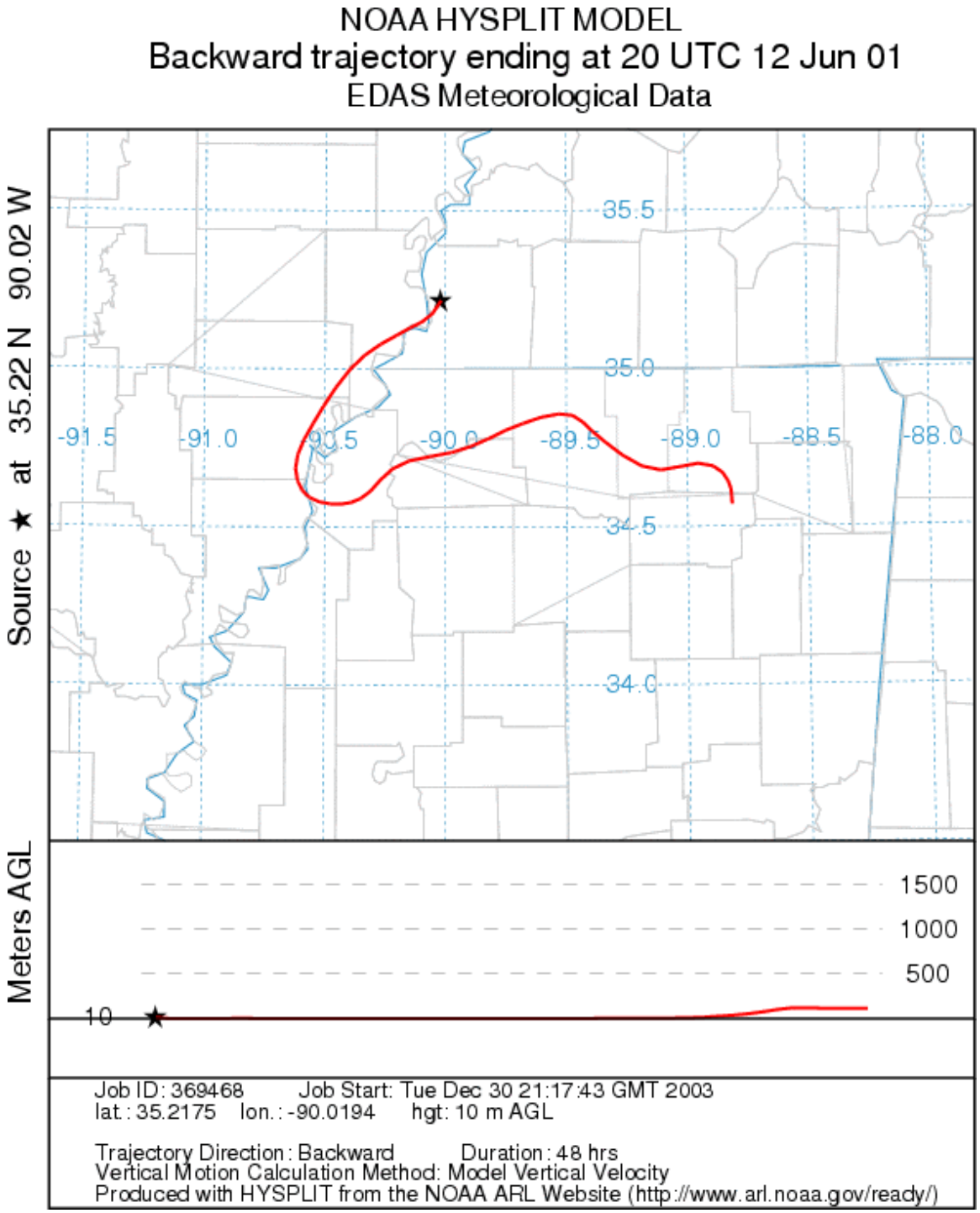
Moderate southerly transport winds originating in east central Louisiana and flowing through eastern Louisiana and northwestern Mississippi before arriving at the Memphis ozone monitor.

Memphis, Tennessee Monitor 48-Hour Back Trajectory for the Period Ending August 22, 2000
Maximum 8-Hour Average – 104 ppb – 2nd Max



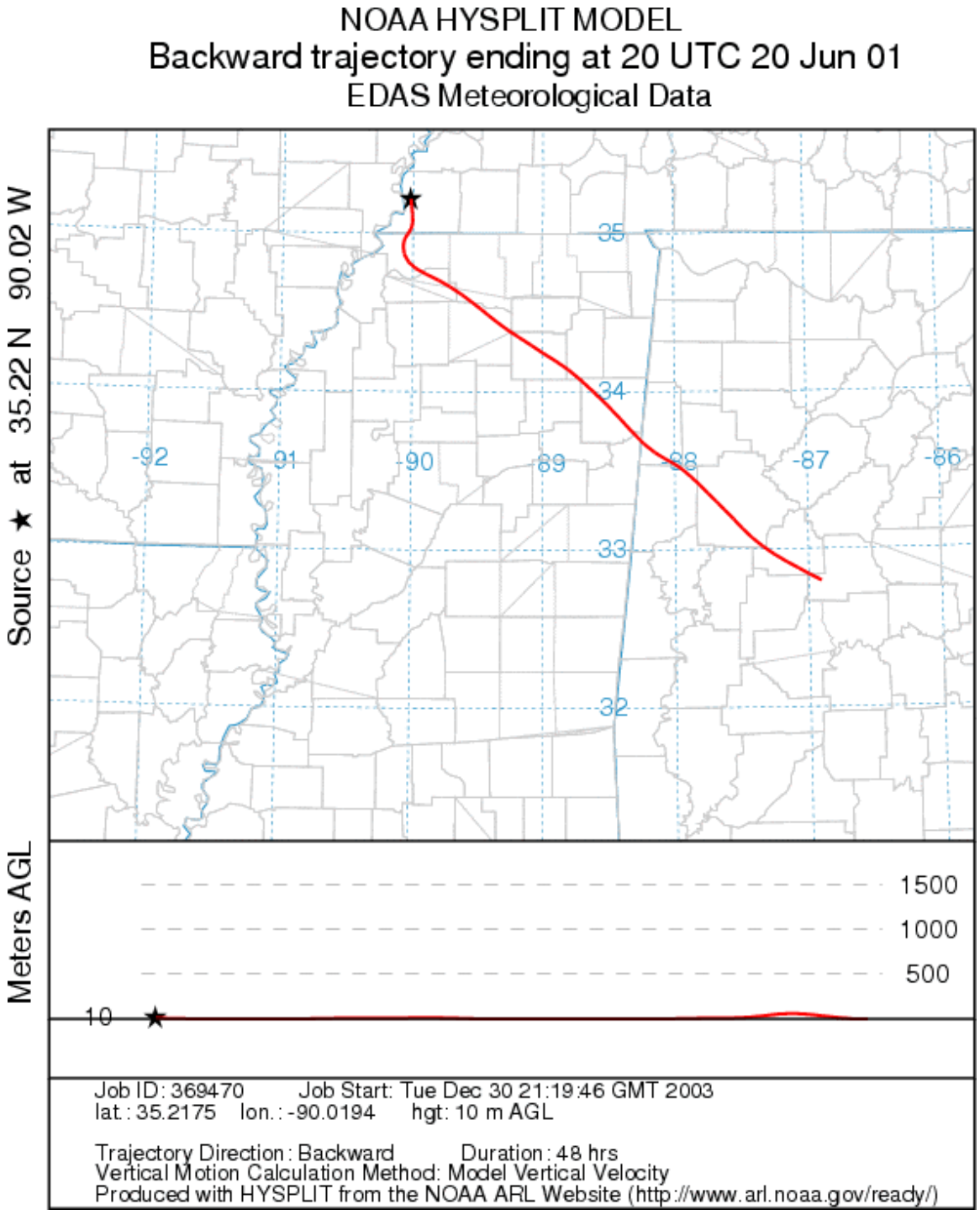
Moderate easterly transport winds originating in northwestern Georgia and flowing though northern Alabama and northern Mississippi becoming southeasterly before arriving at the Memphis ozone monitor.

Memphis, Tennessee Monitor 48-Hour Back Trajectory for the Period Ending June 12, 2001
Maximum 8-Hour Average – 114 ppb – 1st Max



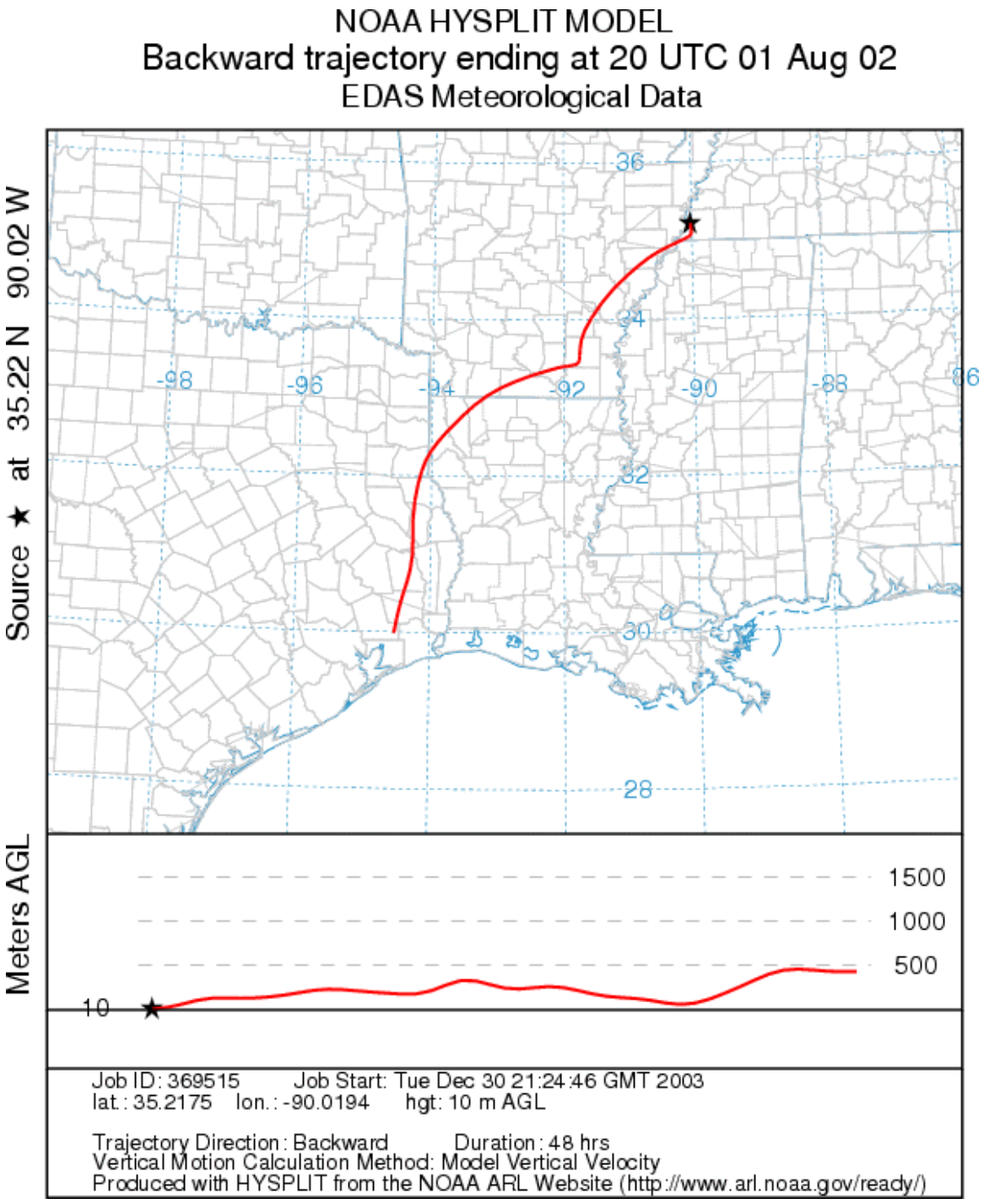
Light and variable transport winds originating in northern Mississippi and flowing through eastern Arkansas before arriving at the Memphis ozone monitor.

Memphis, Tennessee Monitor 48-Hour Back Trajectory for the Period Ending June 20, 2001
Maximum 8-Hour Average – 93 ppb – 2nd Max



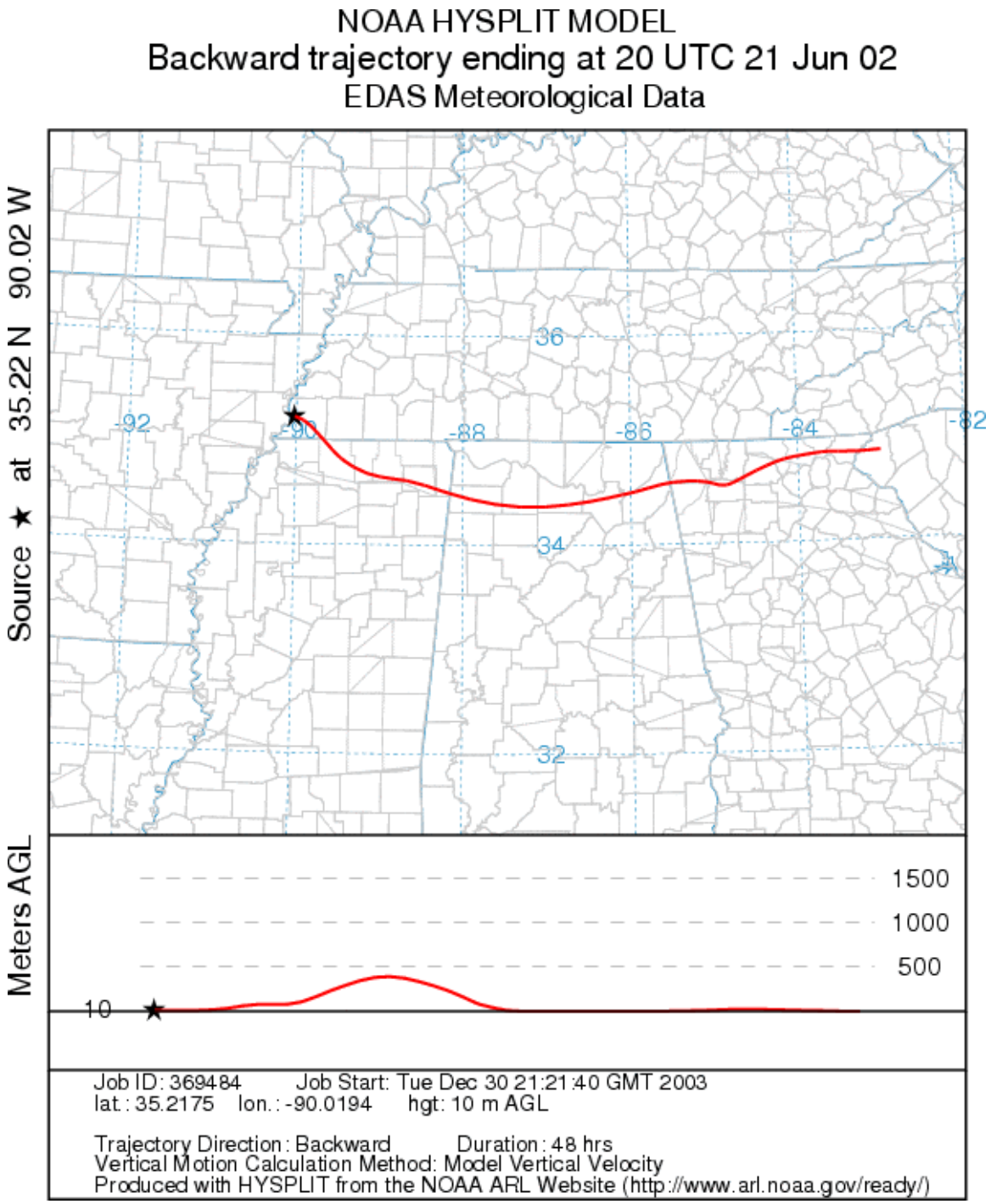
Light southeasterly transport winds originating in central Alabama and flowing through northern Mississippi before arriving at the Memphis ozone monitor.

Memphis, Tennessee Monitor 48-Hour Back Trajectory for the Period Ending August 1, 2002
Maximum 8-Hour Average – 93 ppb – 1st Max



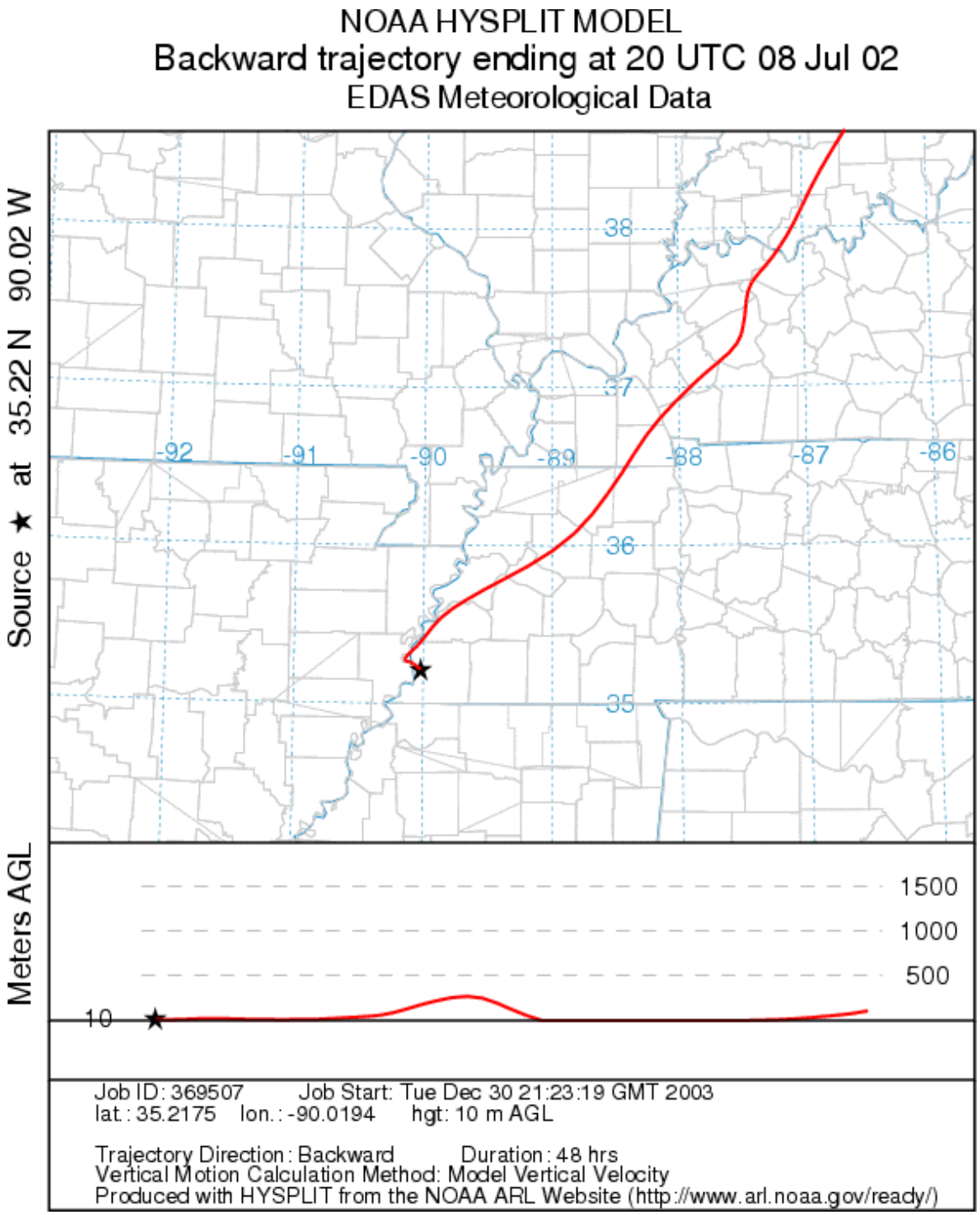
Moderate southwesterly transport winds originating in southeastern Texas and flowing through eastern Texas, northwestern Louisiana, and southern and eastern Arkansas before arriving at the Memphis ozone monitor.

Memphis, Tennessee Monitor 48-Hour Back Trajectory for the Period Ending June 21, 2002
Maximum 8-Hour Average – 91 ppb – 2nd Max



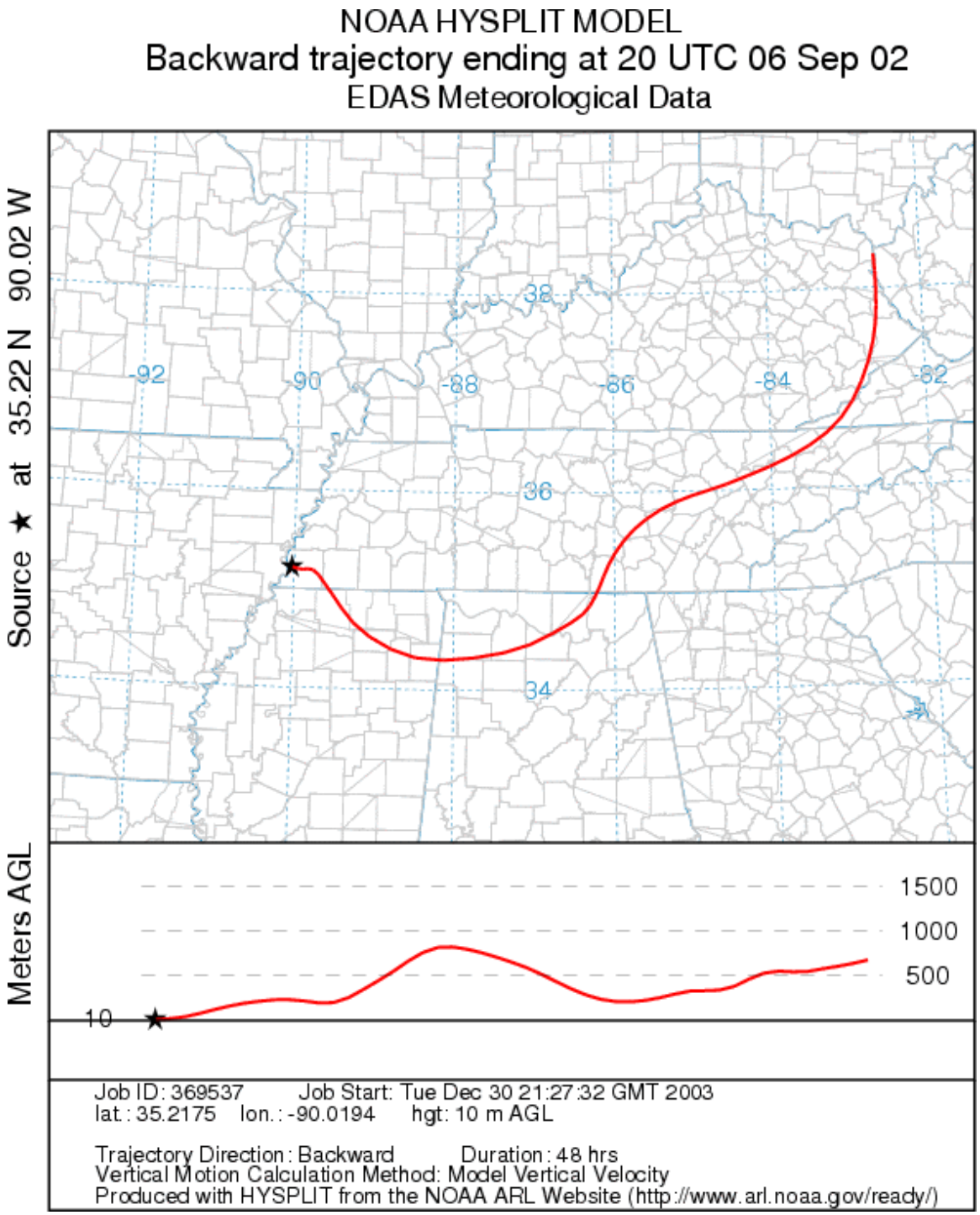
Moderate easterly transport winds originating in northwestern South Carolina and flowing through northern Georgia, northern Alabama, and northern Mississippi before arriving at the Memphis ozone monitor.

Memphis, Tennessee Monitor 48-Hour Back Trajectory for the Period Ending July 8, 2002
Maximum 8-Hour Average – 88 ppb – 3rd Max



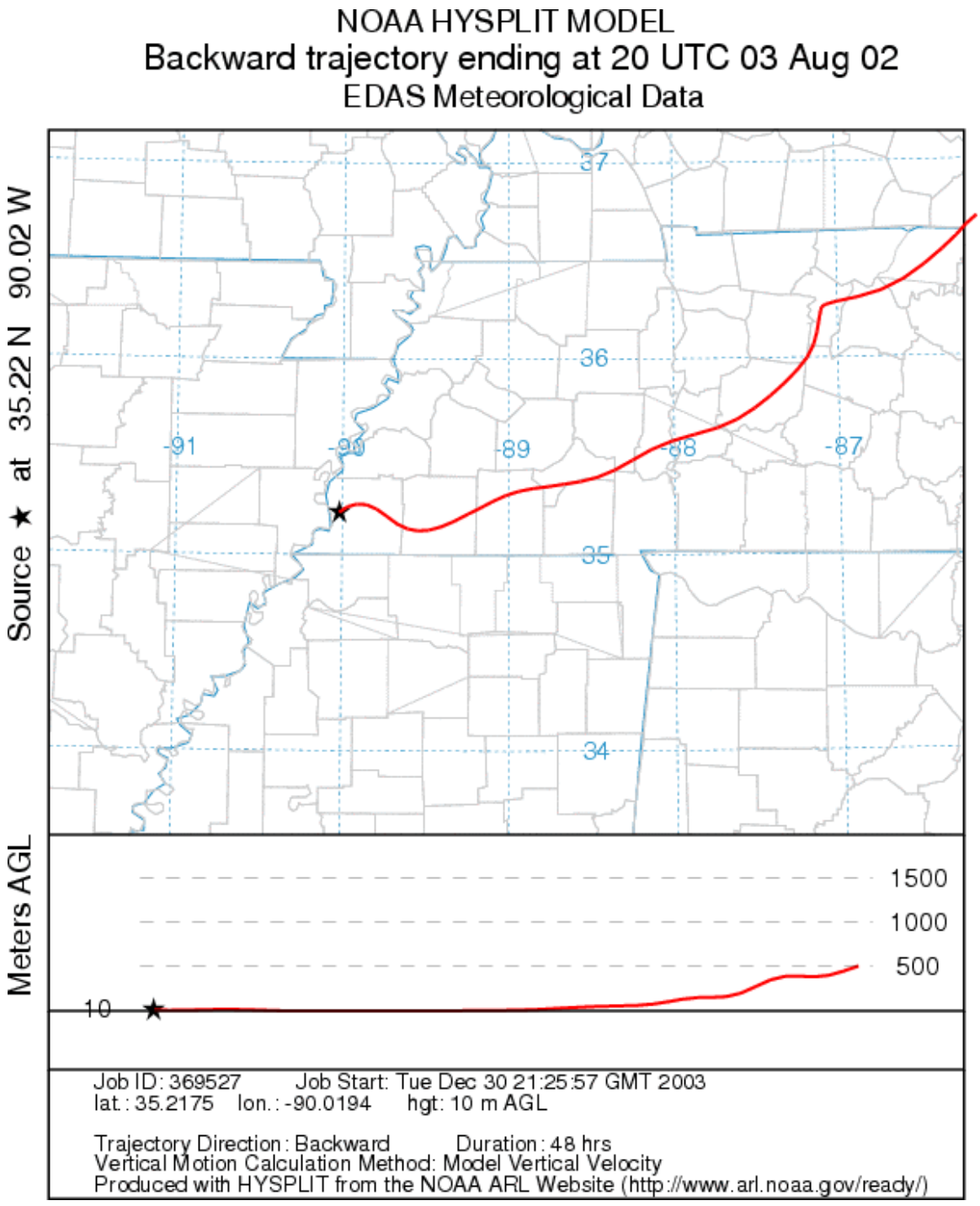
Moderate northeasterly transport winds originating in southern Indiana and flowing through western Kentucky and western Tennessee before arriving at the Memphis ozone monitor.

Memphis, Tennessee Monitor 48-Hour Back Trajectory for the Period Ending September 6, 2002
Maximum 8-Hour Average – 86 ppb – 4th Max



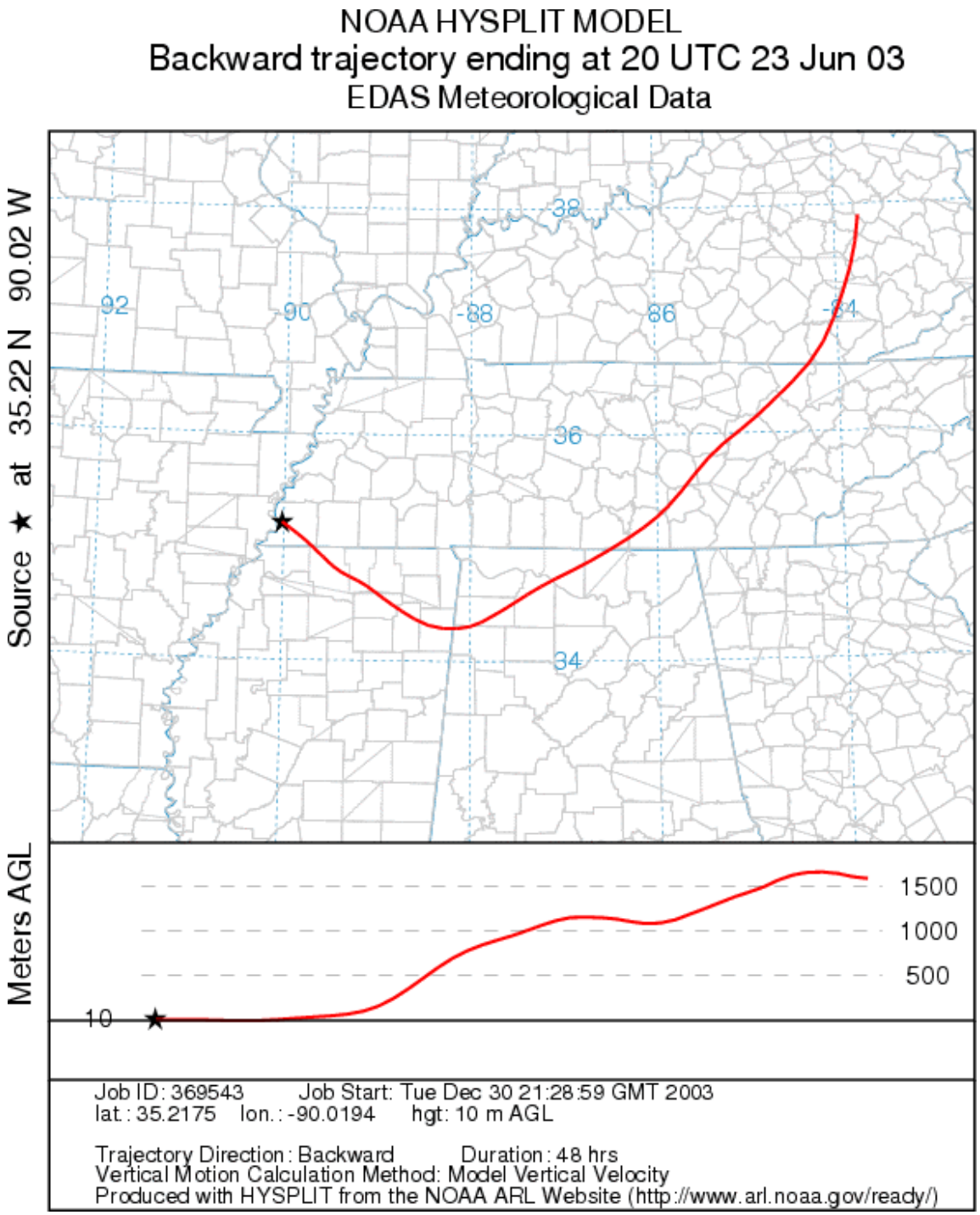
Moderate northeasterly transport winds originating in eastern Kentucky and flowing through eastern Tennessee and northern Alabama becoming southeasterly through northern Mississippi before arriving at the Memphis ozone monitor.

Memphis, Tennessee Monitor 48-Hour Back Trajectory for the Period Ending August 3, 2002
Maximum 8-Hour Average – 85 ppb – 5th Max



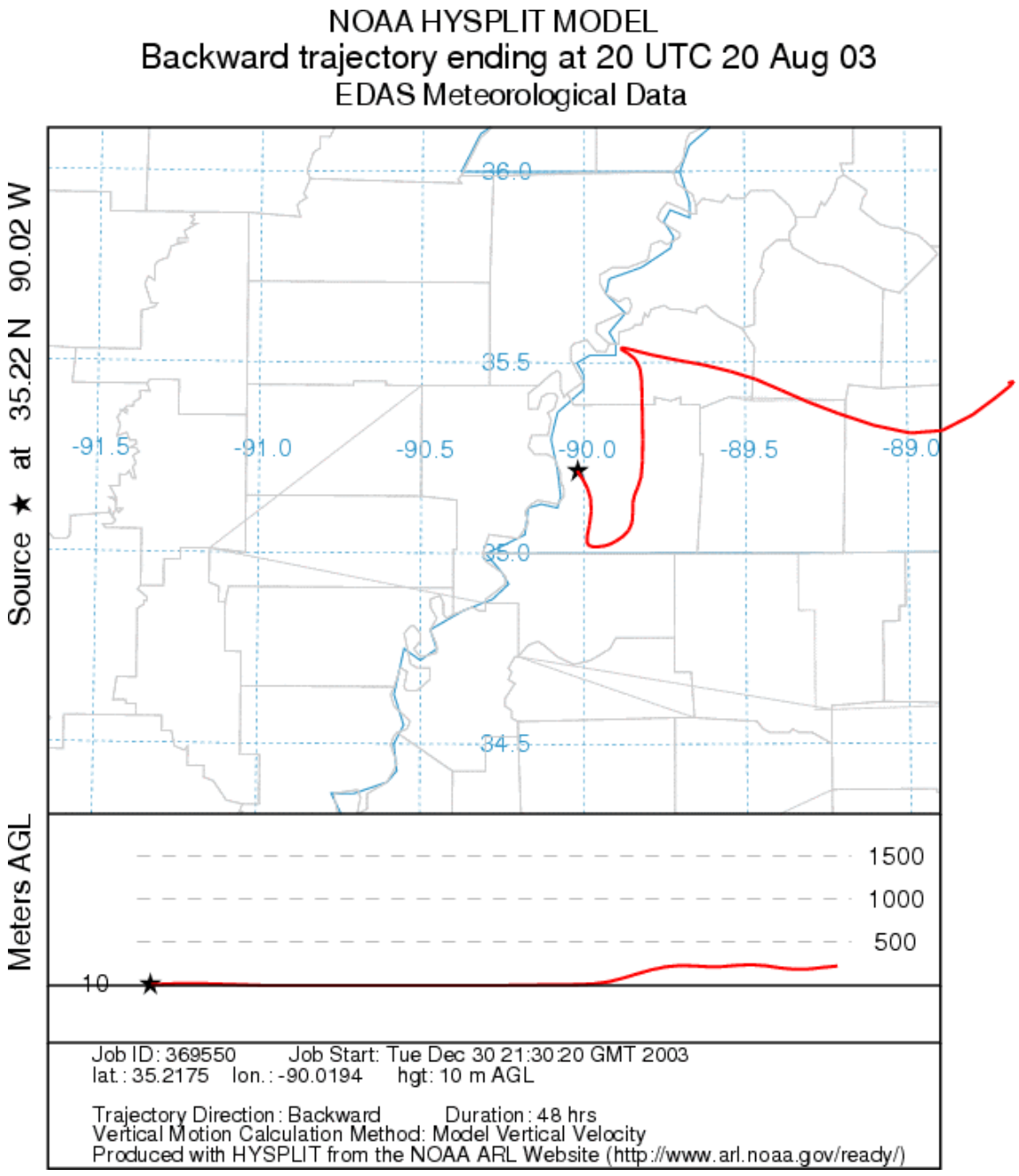
Light easterly transport winds originating in north central Tennessee and flowing through central and southwestern Tennessee before arriving at the Memphis ozone monitor.

Memphis, Tennessee Monitor 48-Hour Back Trajectory for the Period Ending June 23, 2003
Maximum 8-Hour Average – 94 ppb – 1st Max



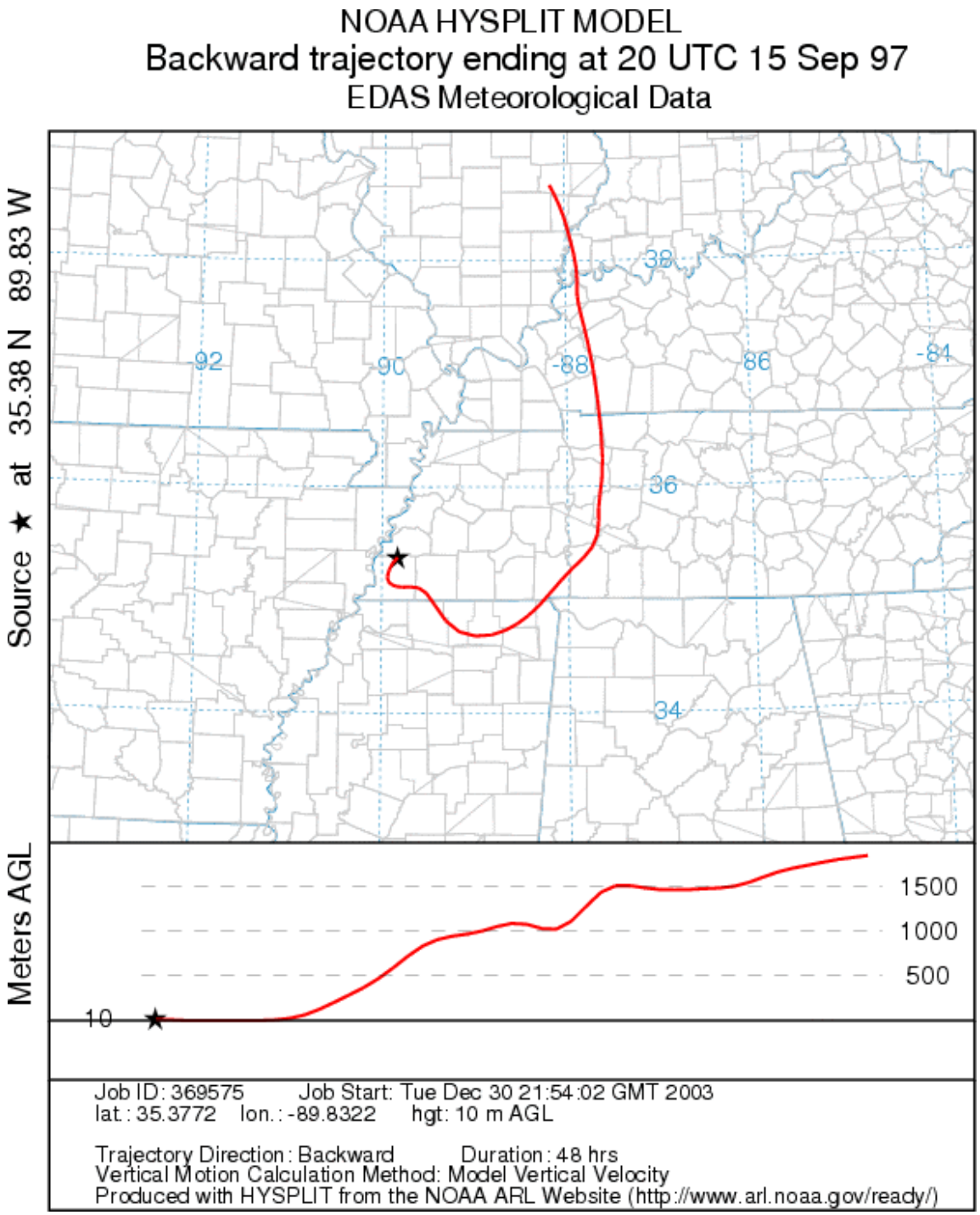
Moderate northeasterly transport winds originating in eastern Kentucky and flowing through central Tennessee and northwestern Alabama becoming southeasterly in northern Mississippi before arriving at the Memphis ozone monitor.

Memphis, Tennessee Monitor 48-Hour Back Trajectory for the Period Ending August 20, 2003
Maximum 8-Hour Average – 87 ppb – 2nd Max



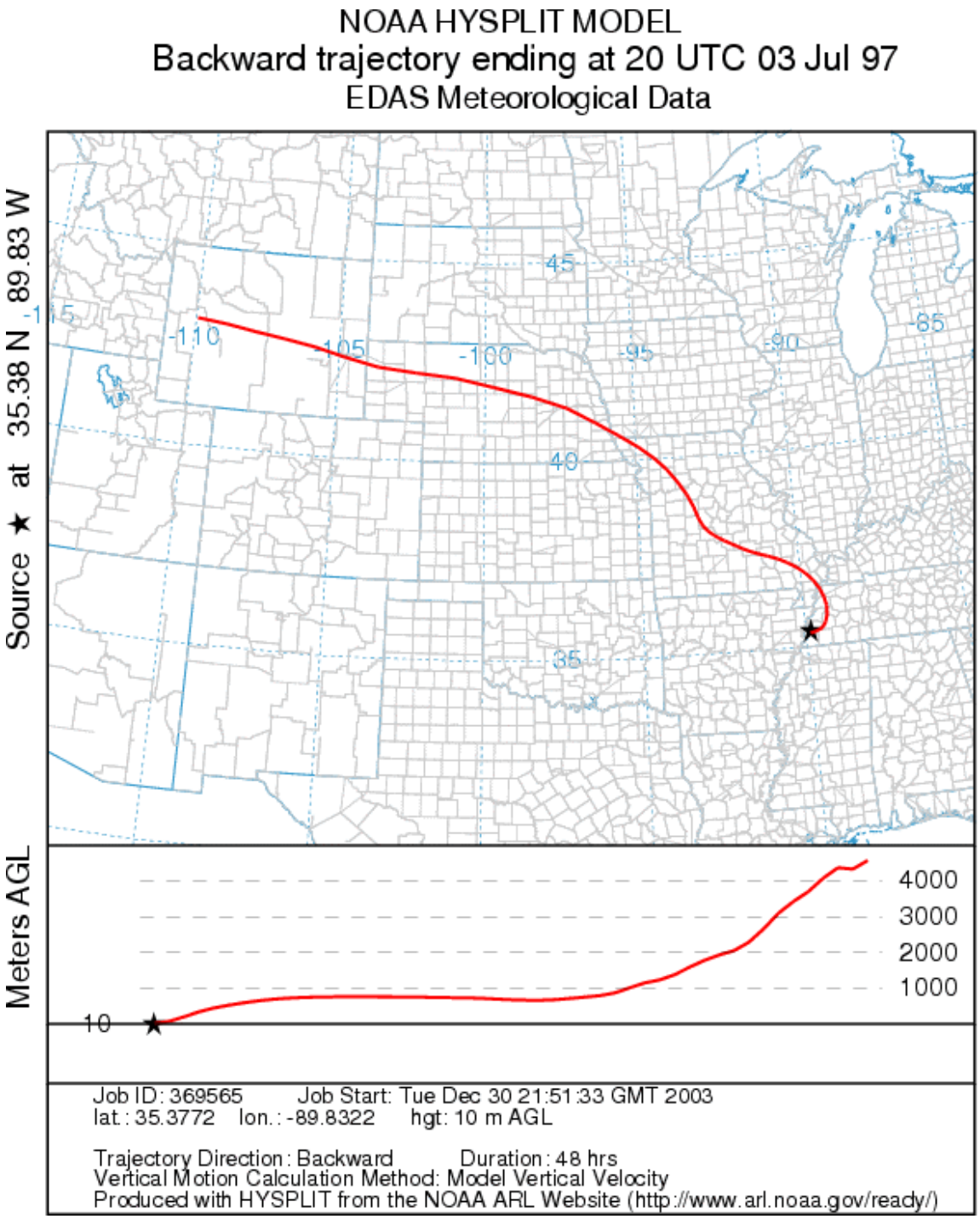
Light and variable transport winds flowing through southwestern Tennessee before arriving at the Memphis ozone monitor.

Edmond Orgill Park, Tennessee Monitor 48-Hour Back Trajectory for the Period Ending September 15, 1997
Maximum 8-Hour Average – 98 ppb – 1st Max



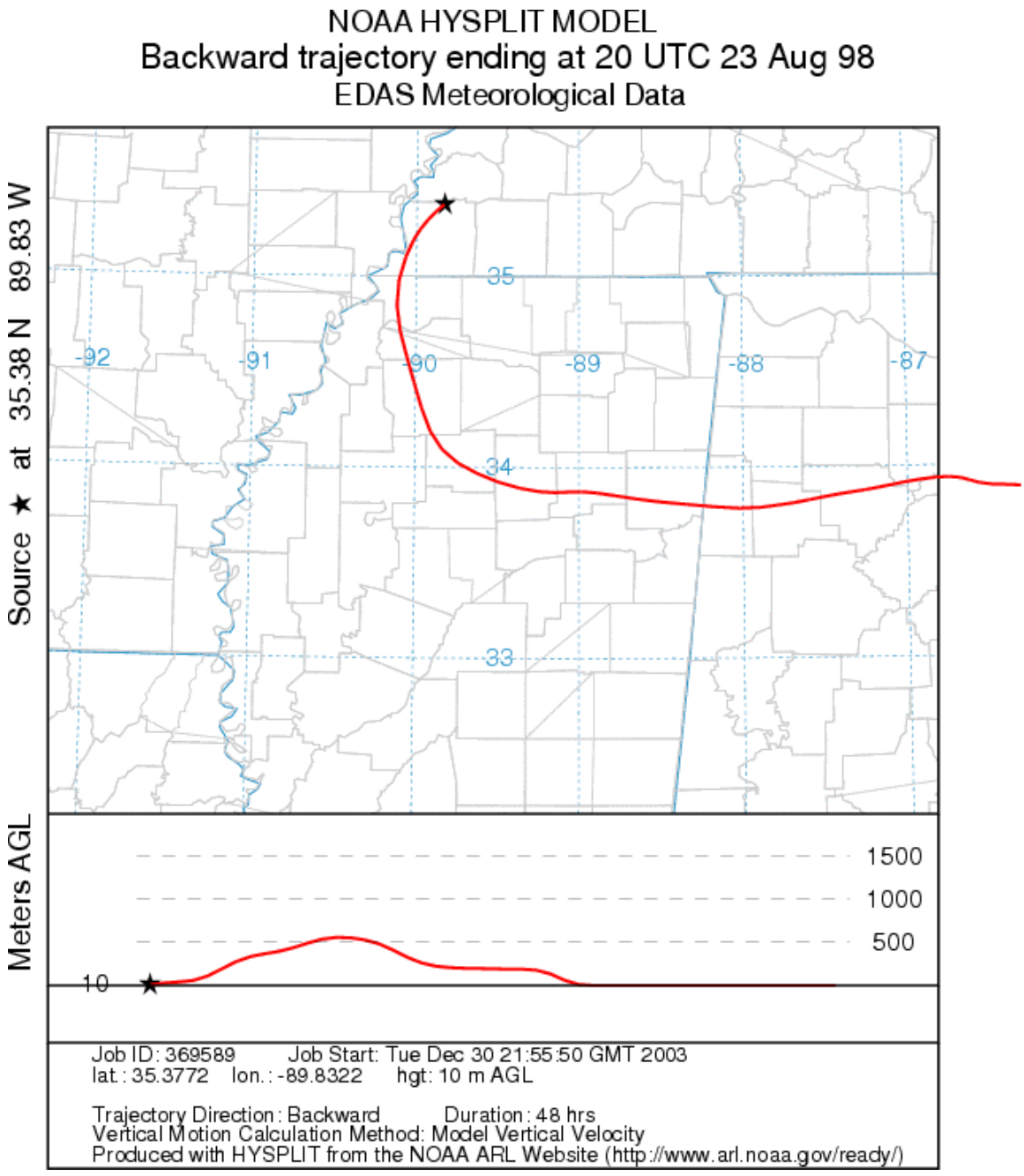
Moderate northerly transport winds originating in southeastern Illinois and flowing through western Kentucky, western Tennessee, and northern Mississippi becoming light and variable before arriving at the E. O. Park ozone monitor.

Edmond Orgill Park, Tennessee Monitor 48-Hour Back Trajectory for the Period Ending July 3, 1997
Maximum 8-Hour Average – 89 ppb – 2nd Max



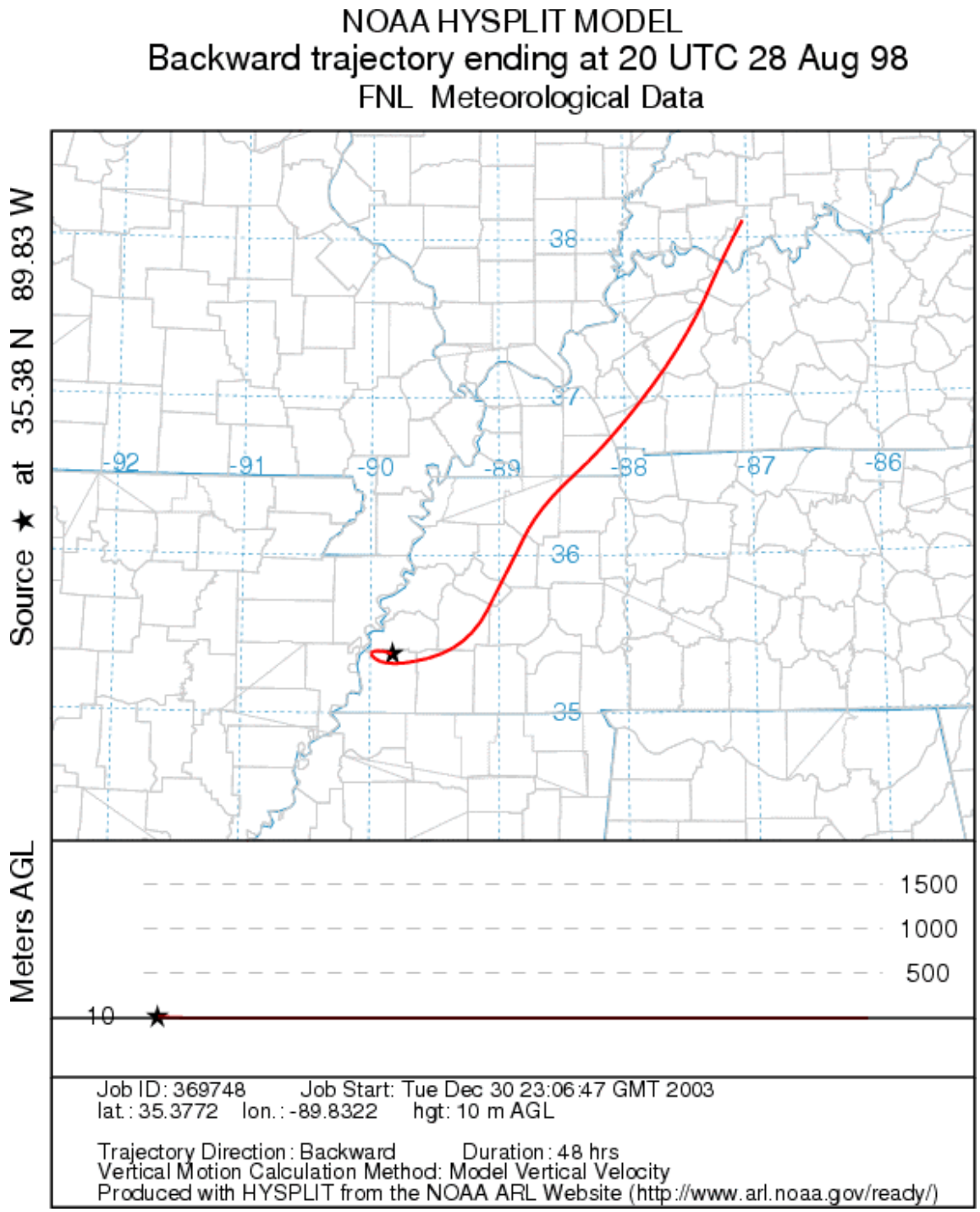
Strong northwesterly transport winds originating in western Wyoming flowing through central Nebraska, central Missouri, and western Tennessee before arriving at the E. O. Park ozone monitor.

Edmond Orgill Park, Tennessee Monitor 48-Hour Back Trajectory for the Period Ending August 23, 1998
Maximum 8-Hour Average – 108 ppb – 1st Max



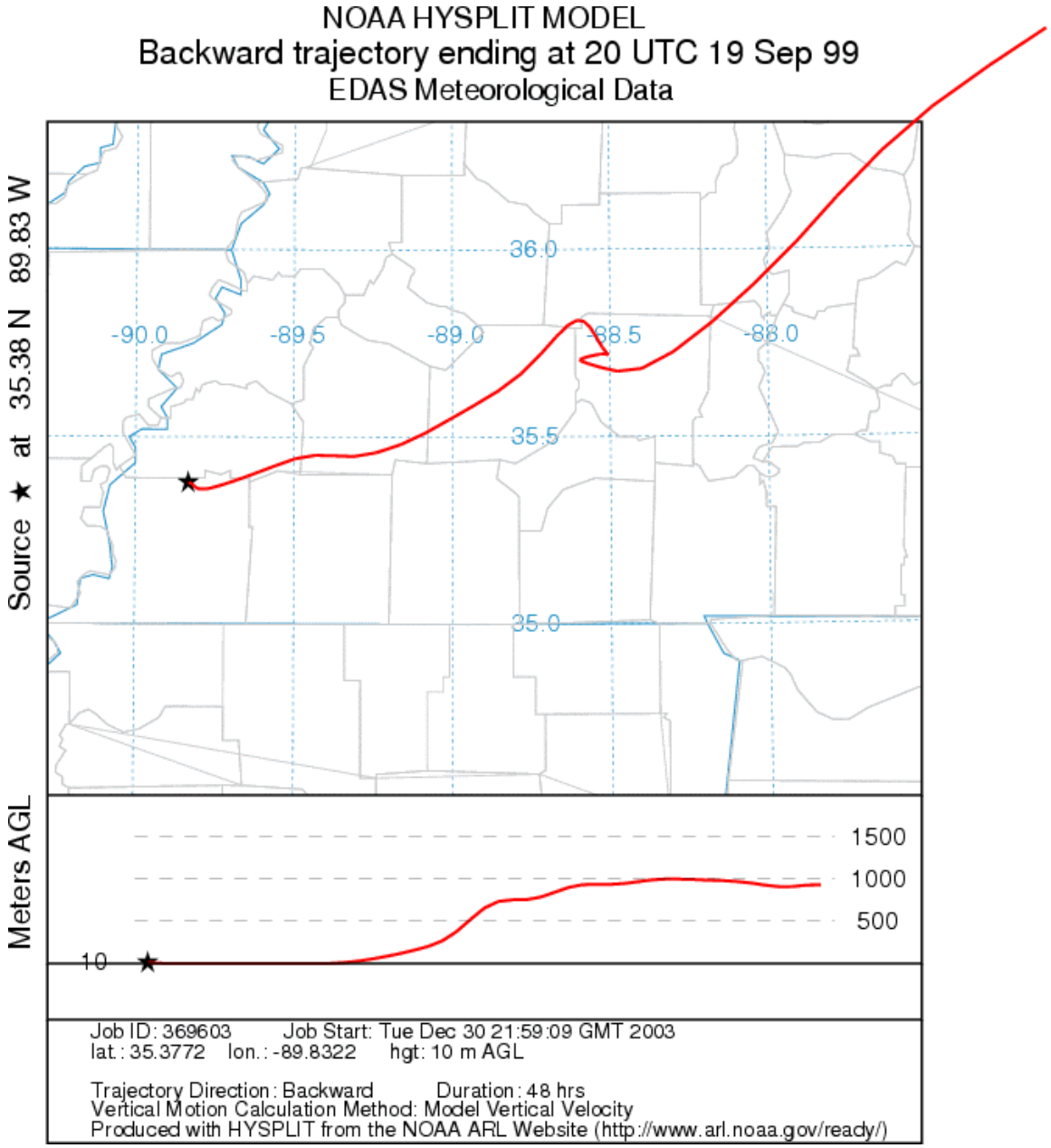
Light easterly transport winds originating in northern Alabama and flowing through northern Mississippi becoming southerly before arriving at the E. O. Park ozone monitor.

Edmond Orgill Park, Tennessee Monitor 48-Hour Back Trajectory for the Period Ending August 28, 1998
Maximum 8-Hour Average – 108 ppb – 2nd Max



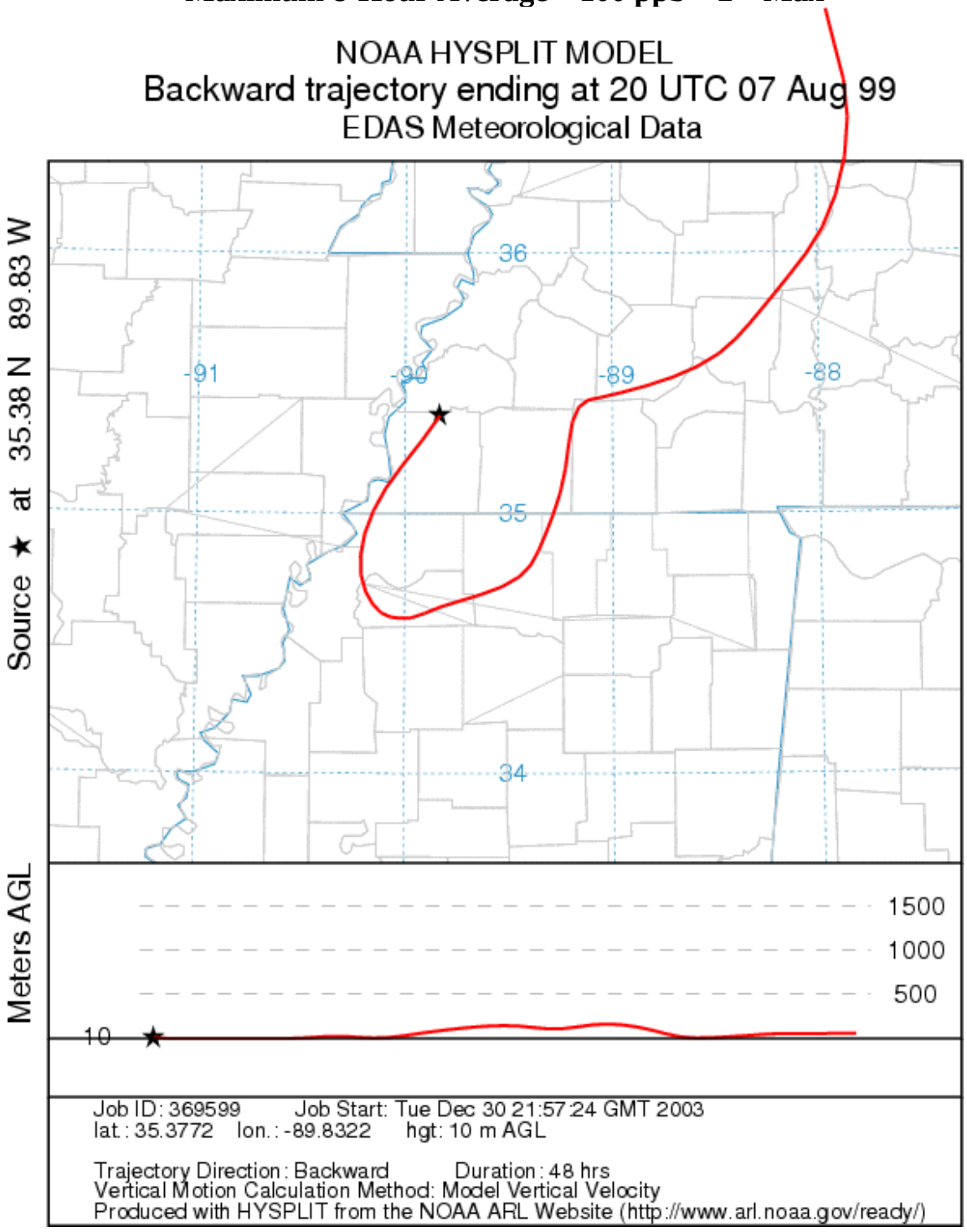
Moderate northeasterly transport winds originating in southern Indiana and flowing through western Kentucky and western Tennessee before arriving at the E. O. Park ozone monitor.

Edmond Orgill Park, Tennessee Monitor 48-Hour Back Trajectory for the Period Ending September 19, 1999
Maximum 8-Hour Average – 102 ppb – 1st Max



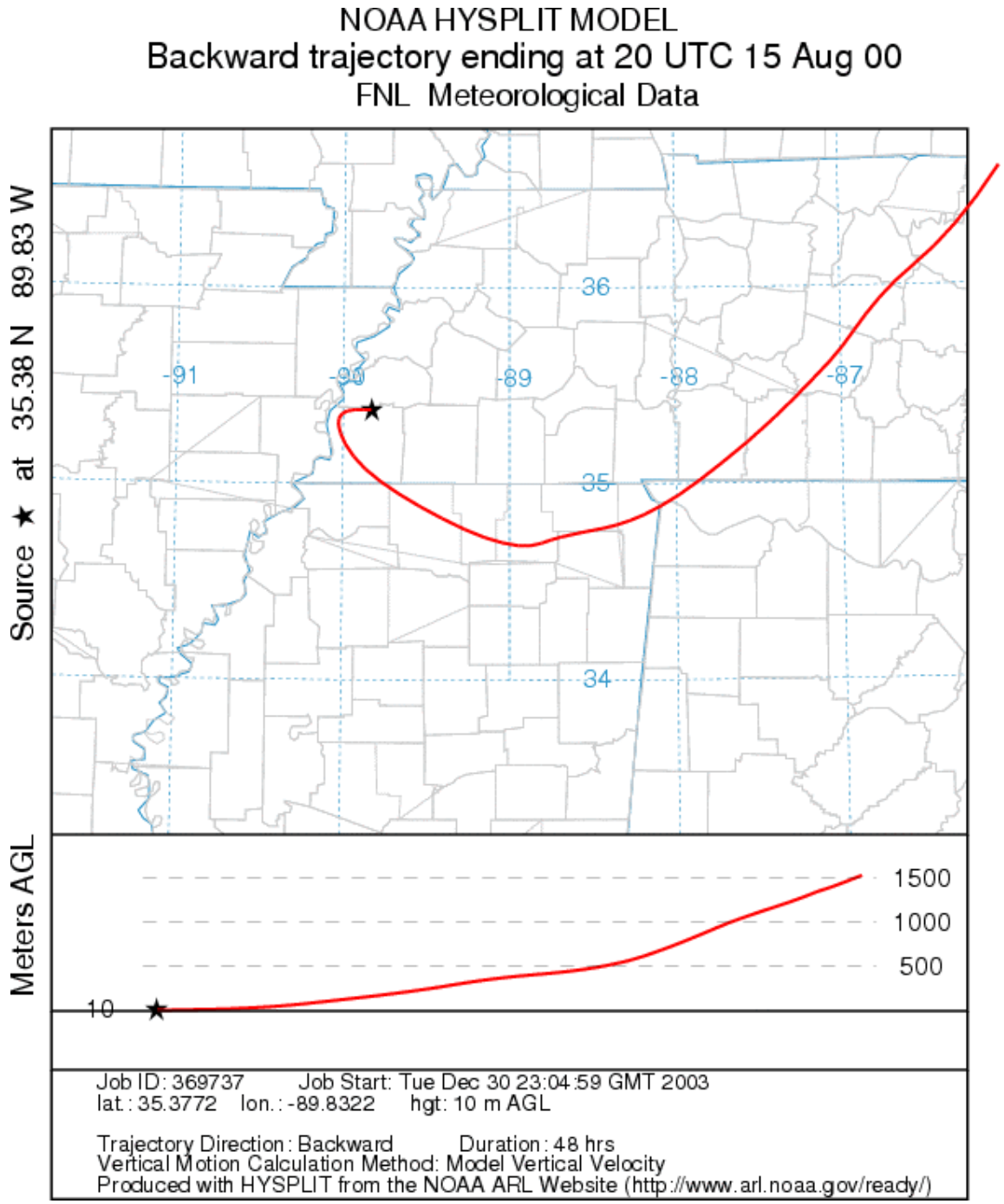
Light and variable transport winds originating in north central Tennessee and flowing through western Tennessee before arriving at the E. O. Park ozone monitor.

Edmond Orgill Park, Tennessee Monitor 48-Hour Back Trajectory for the Period Ending August 7, 1999
Maximum 8-Hour Average – 100 ppb – 2nd Max



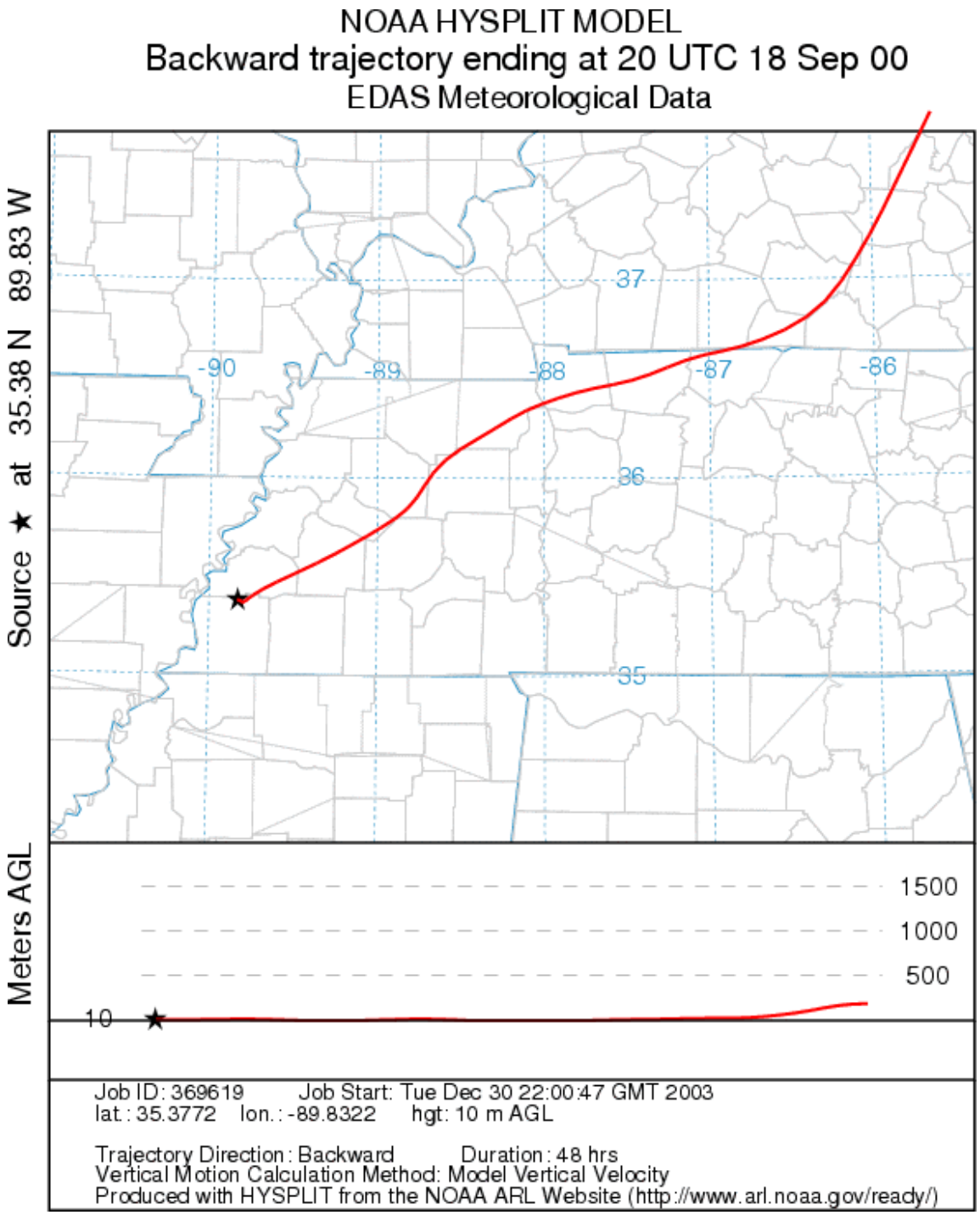
Light northeasterly transport winds originating in western Tennessee and flowing through northern Mississippi becoming southerly before arriving at the E. O. Park ozone monitor.

Edmond Orgill Park, Tennessee Monitor 48-Hour Back Trajectory for the Period Ending August 15, 2000
Maximum 8-Hour Average – 98 ppb – 1st Max



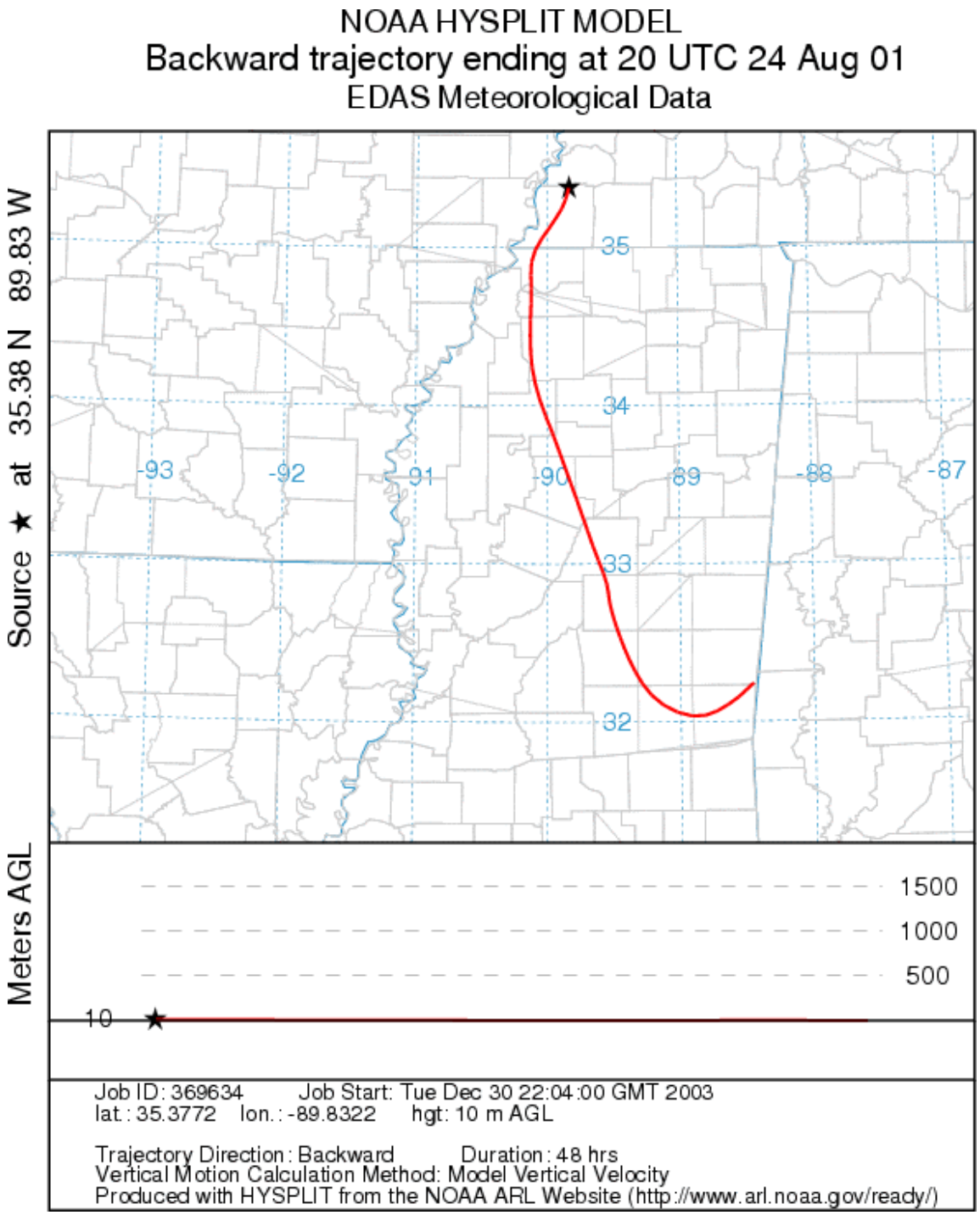
Light transport winds originating in central Tennessee and flowing through northern Mississippi before arriving at the E. O. Park ozone monitor.

Edmond Orgill Park, Tennessee Monitor 48-Hour Back Trajectory for the Period Ending September 18, 2000
Maximum 8-Hour Average – 98 ppb – 2nd Max



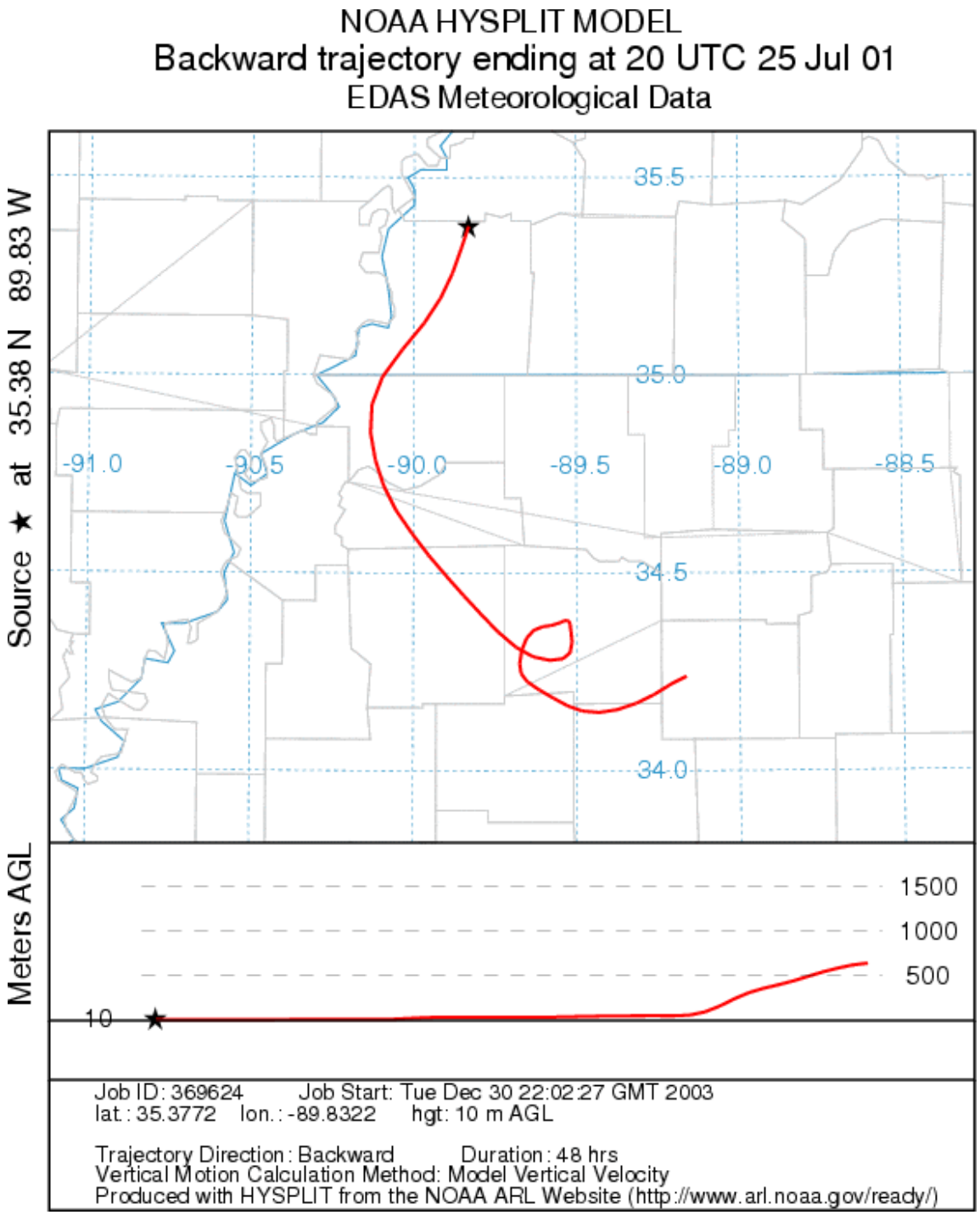
Light northeasterly transport winds originating in central Kentucky and flowing through western Tennessee before arriving at the E. O. Park ozone monitor.

Edmond Orgill Park, Tennessee Monitor 48-Hour Back Trajectory for the Period Ending August 24, 2001
Maximum 8-Hour Average – 101 ppb – 1st Max



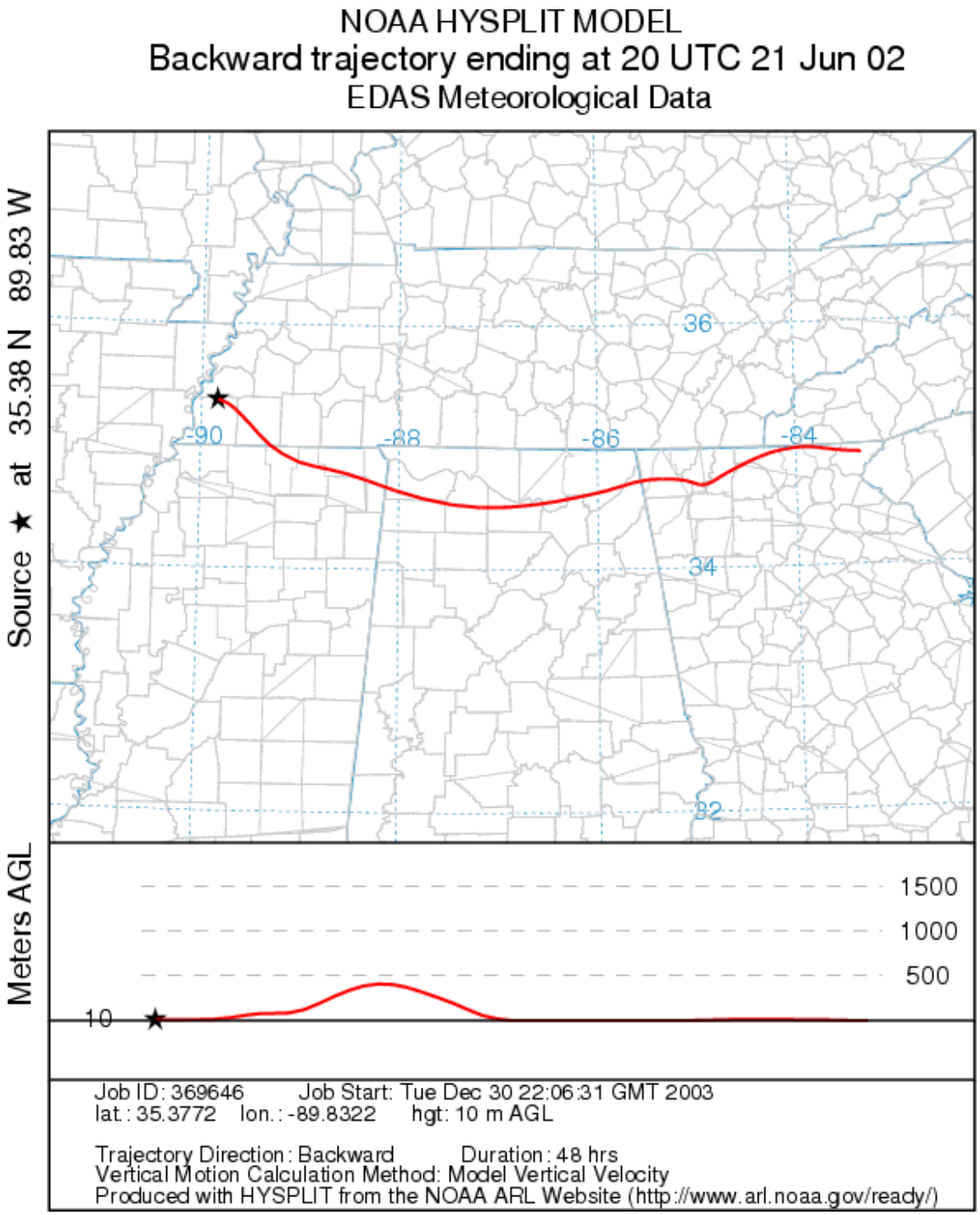
Light southerly transport winds originating in east central Mississippi and flowing through central and northwestern Mississippi before arriving at the E. O. Park ozone monitor.

Edmond Orgill Park, Tennessee Monitor 48-Hour Back Trajectory for the Period Ending July 25, 2001
Maximum 8-Hour Average – 95 ppb – 2nd Max



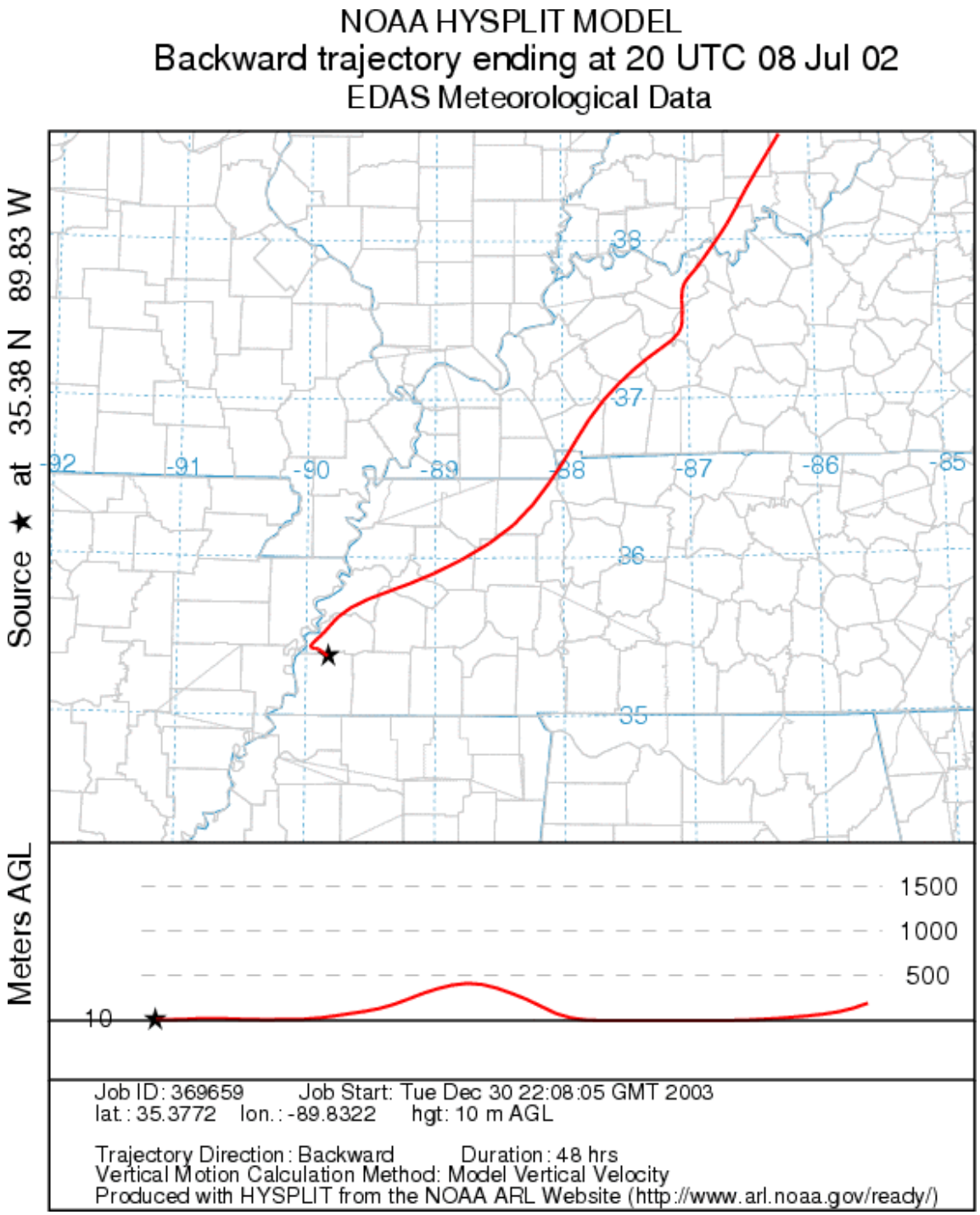
Light and variable transport winds originating in northern Mississippi flowing through northwestern Mississippi before arriving at the E. O. Park ozone monitor.

Edmond Orgill Park, Tennessee Monitor 48-Hour Back Trajectory for the Period Ending June 21, 2002
Maximum 8-Hour Average – 92 ppb – 1st Max



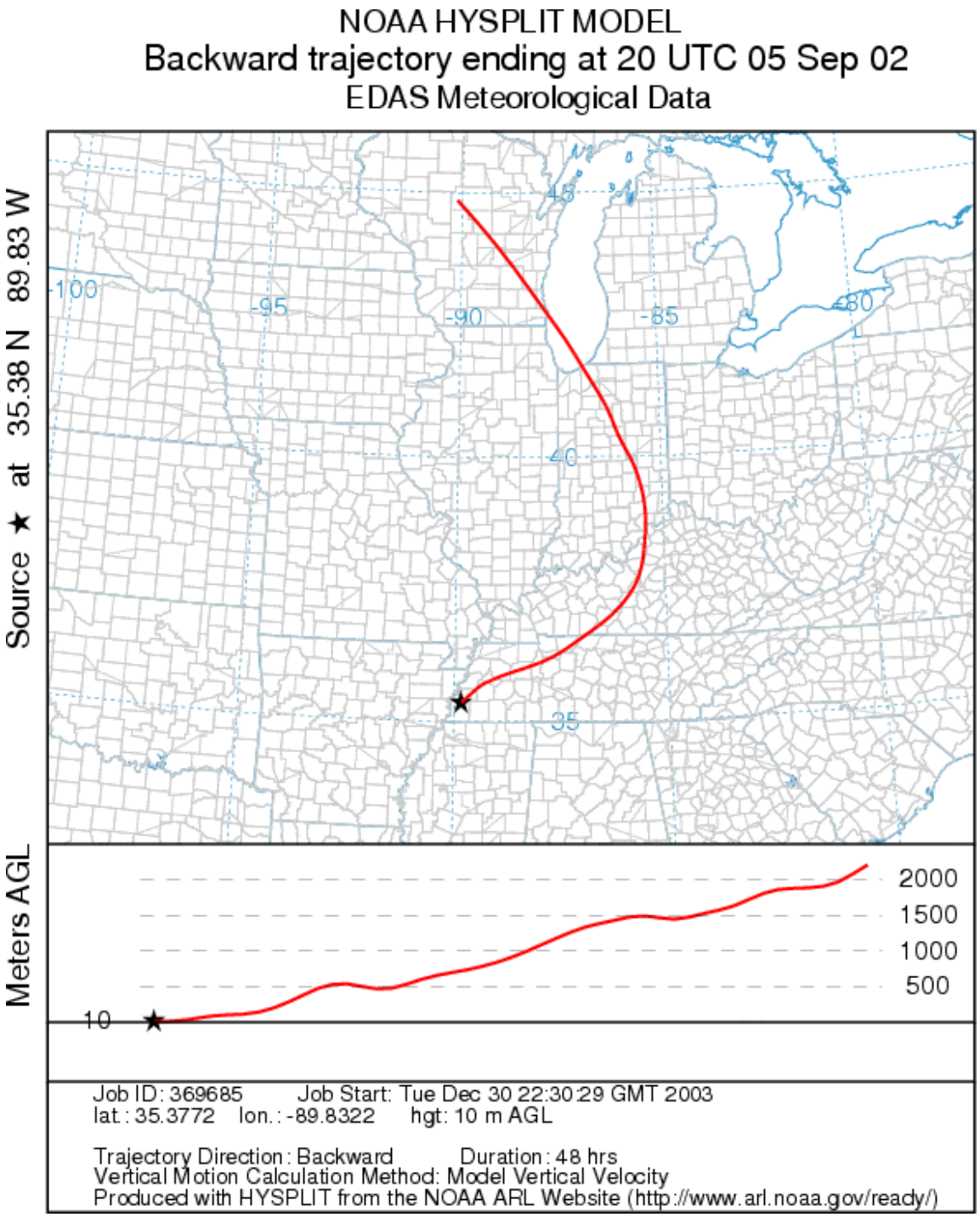
Moderate easterly transport winds originating in northern Georgia, and flowing through northern Alabama and northeastern Mississippi before arriving at the E. O. Park ozone monitor.

Edmond Orgill Park, Tennessee Monitor 48-Hour Back Trajectory for the Period Ending July 8, 2002
Maximum 8-Hour Average – 91 ppb – 2nd Max



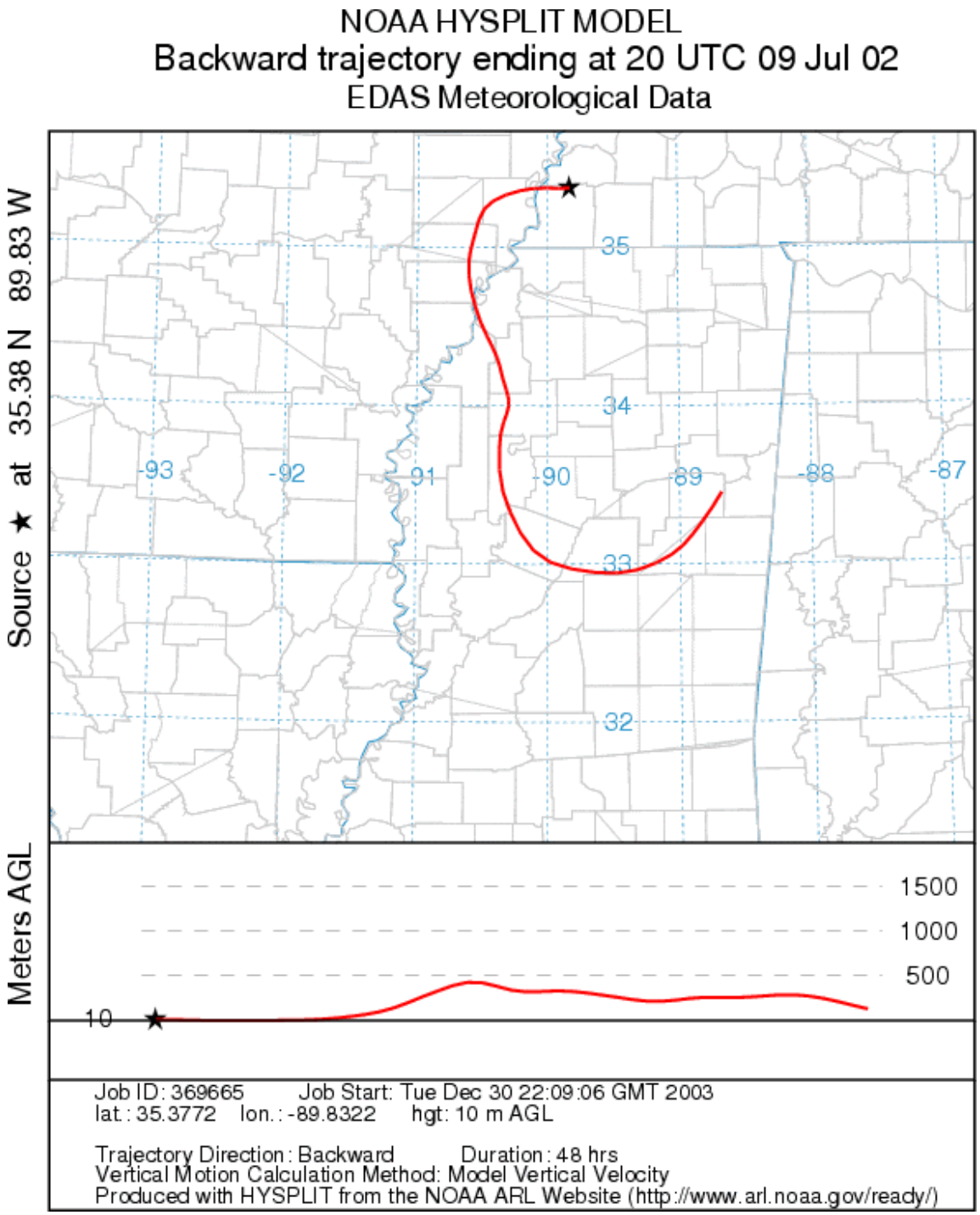
Moderate northeasterly transport winds originating in southern Indiana and flowing through western Kentucky and western Tennessee before arriving at the E. O. Park ozone monitor.

Edmond Orgill Park, Tennessee Monitor 48-Hour Back Trajectory for the Period Ending September 5, 2002
Maximum 8-Hour Average – 89 ppb – 3rd Max



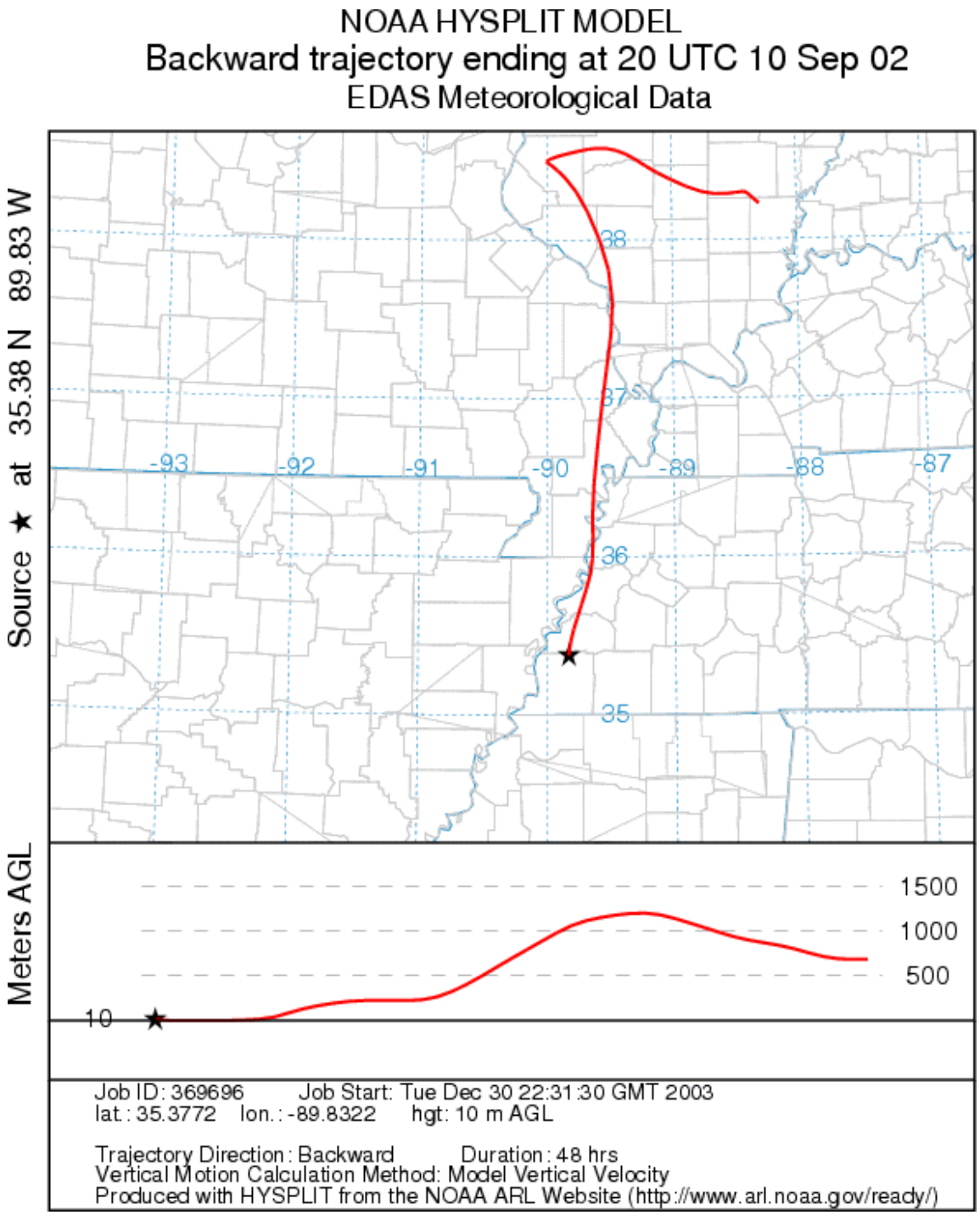
Strong northwesterly transport winds originating in central Wisconsin and flowing through central Indiana becoming northeasterly in central Kentucky and central and western Tennessee before arriving at the E. O. Park ozone monitor.

Edmond Orgill Park, Tennessee Monitor 48-Hour Back Trajectory for the Period Ending July 9, 2002
Maximum 8-Hour Average – 88 ppb – 4th Max



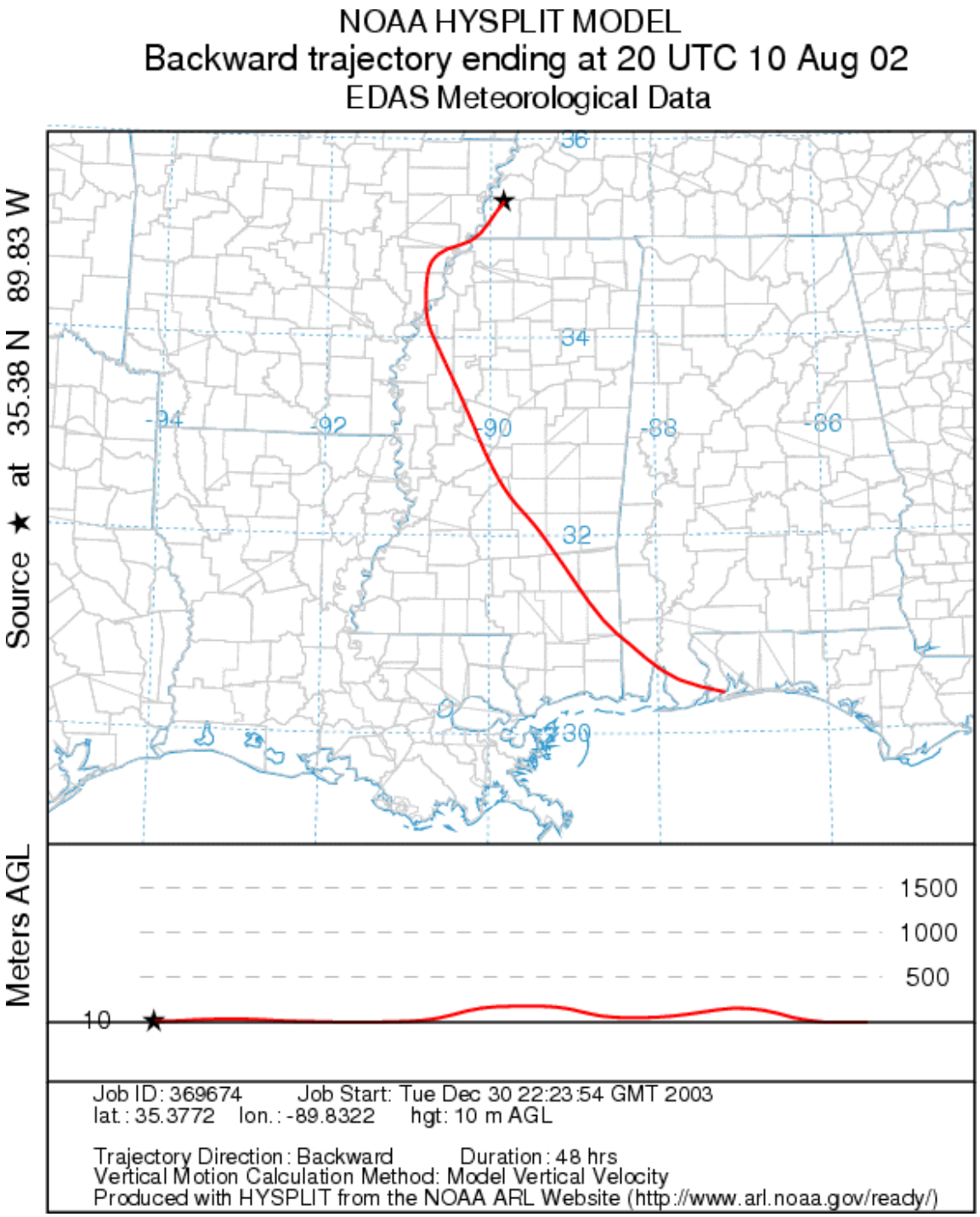
Light and variable transport winds originating in northern Mississippi and flowing though eastern Arkansas before arriving at the E. O. Park ozone monitor.

Edmond Orgill Park, Tennessee Monitor 48-Hour Back Trajectory for the Period Ending September 10, 2002
Maximum 8-Hour Average – 88 ppb – 5th Max



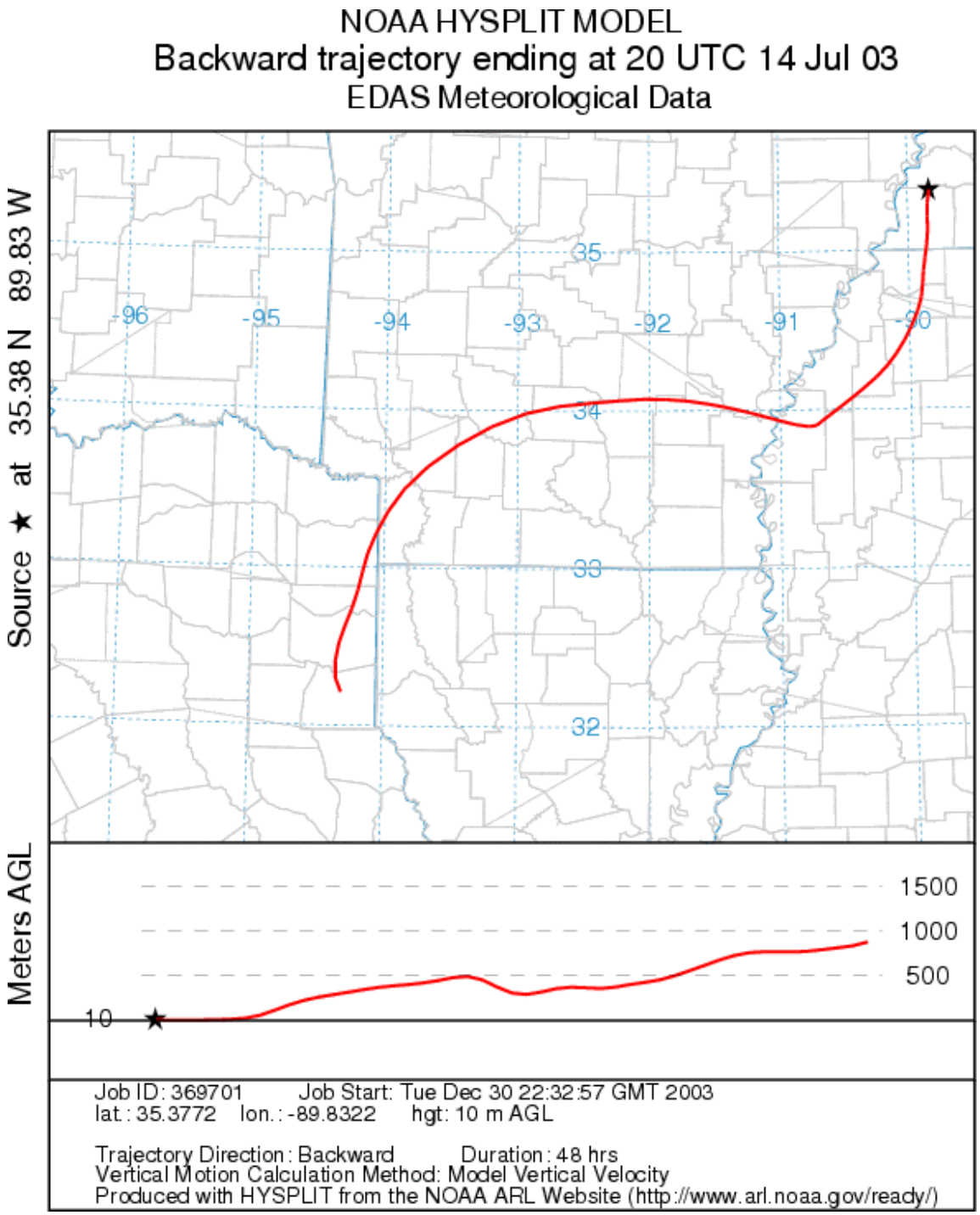
Moderate easterly transport winds originating in southern Illinois becoming northerly through eastern Missouri before arriving at the E. O. Park ozone monitor.

Edmond Orgill Park, Tennessee Monitor 48-Hour Back Trajectory for the Period Ending August 10, 2002
Maximum 8-Hour Average – 86 ppb – 6th Max



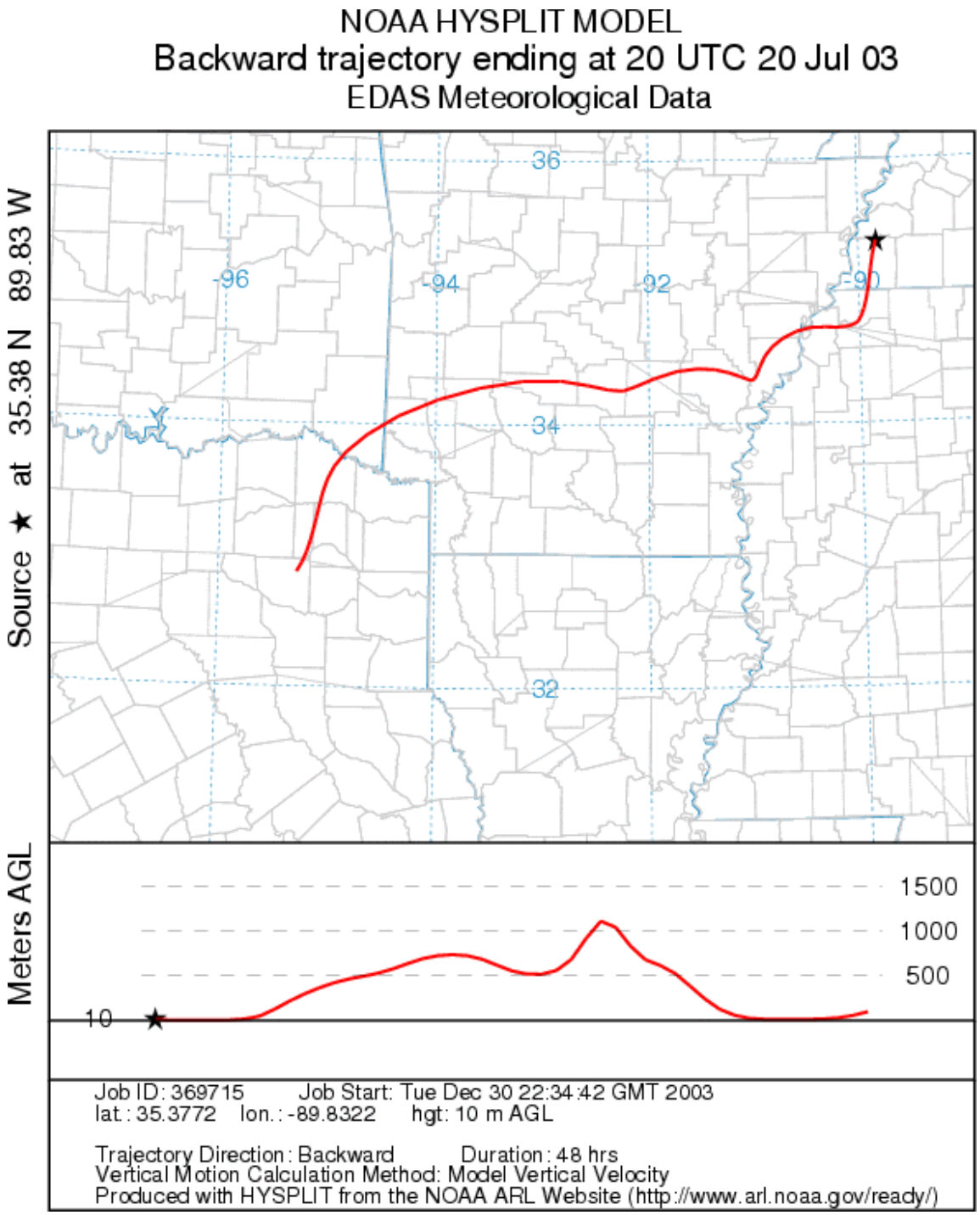
Moderate southeasterly transport winds originating in northwestern Florida and flowing through southwestern Alabama, central Mississippi, and becoming southwesterly along the Mississippi River before arriving at the E. O. Park ozone monitor.

Edmond Orgill Park, Tennessee Monitor 48-Hour Back Trajectory for the Period Ending July 14, 2003
Maximum 8-Hour Average – 91 ppb – 1st Max



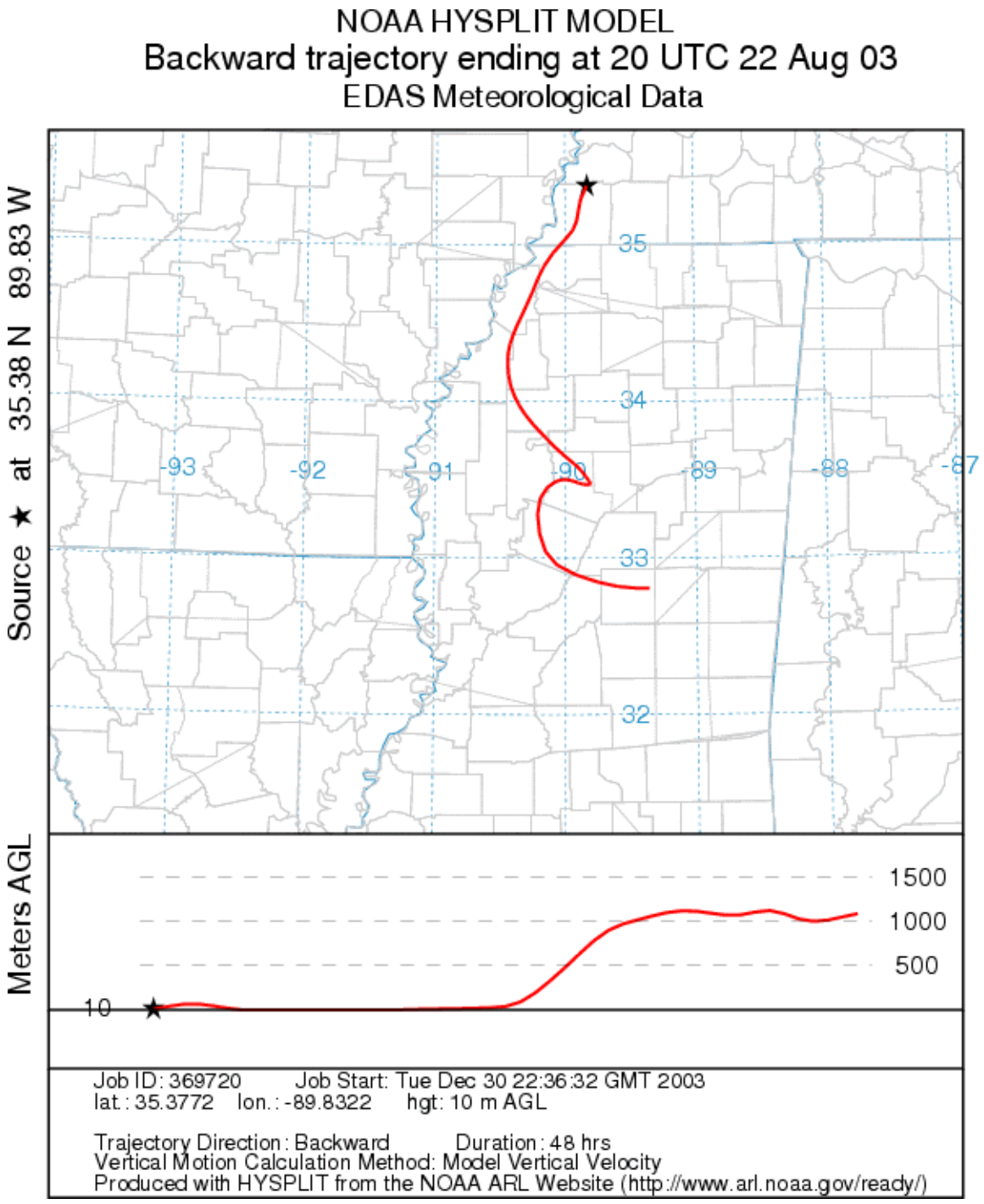
Moderate southwesterly transport winds originating in northeastern Texas and flowing through southern Arkansas and northwestern Mississippi before arriving at the E. O. Park ozone monitor.

Edmond Orgill Park, Tennessee Monitor 48-Hour Back Trajectory for the Period Ending July 20, 2003
Maximum 8-Hour Average – 90 ppb – 2nd Max



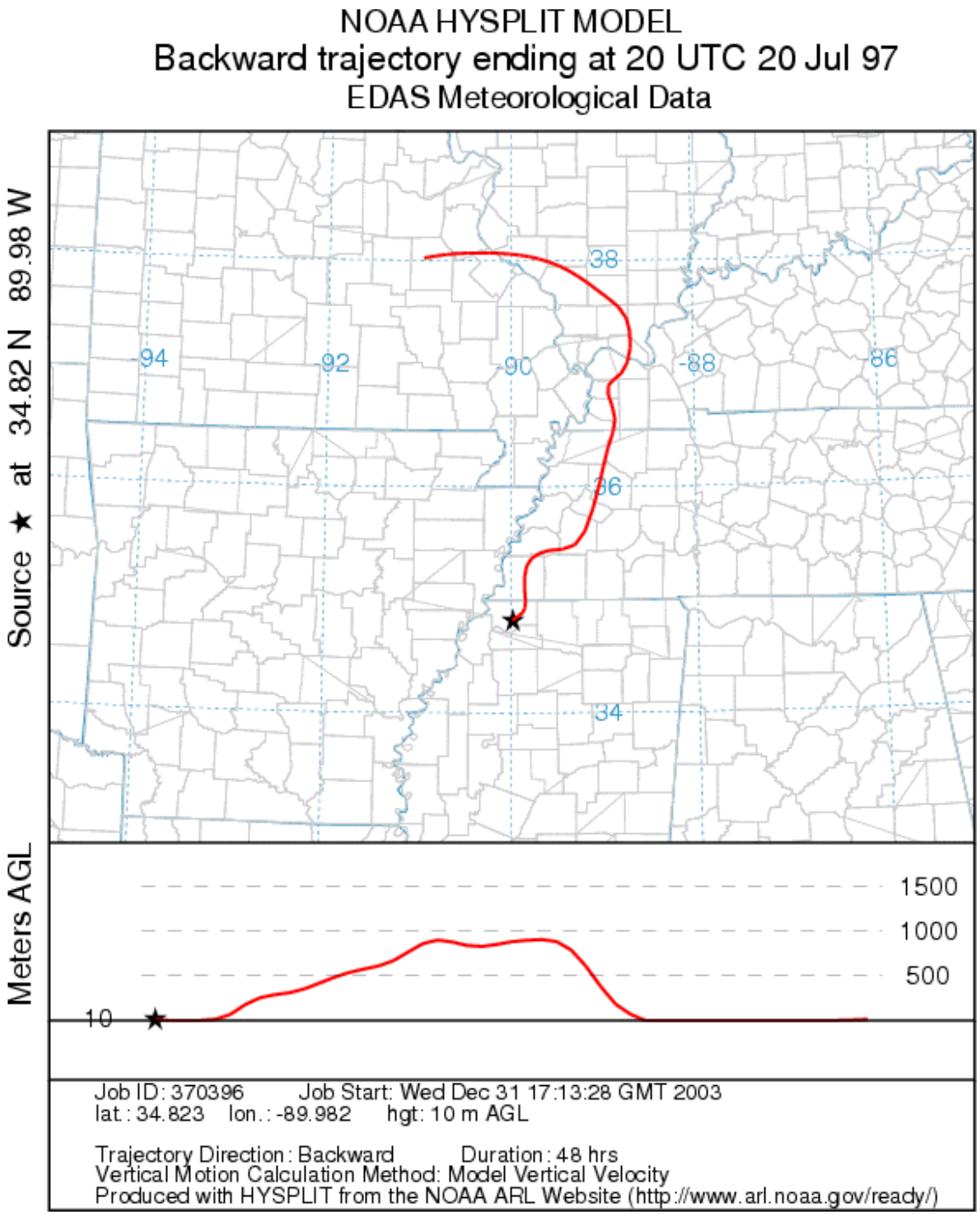
Moderate southerly transport winds originating in northeastern Texas becoming westerly through central Arkansas and northwestern Mississippi becoming southerly again before arriving at the E. O. Park ozone monitor.

Edmond Orgill Park, Tennessee Monitor 48-Hour Back Trajectory for the Period Ending August 22, 2003
Maximum 8-Hour Average – 89 ppb – 3rd Max



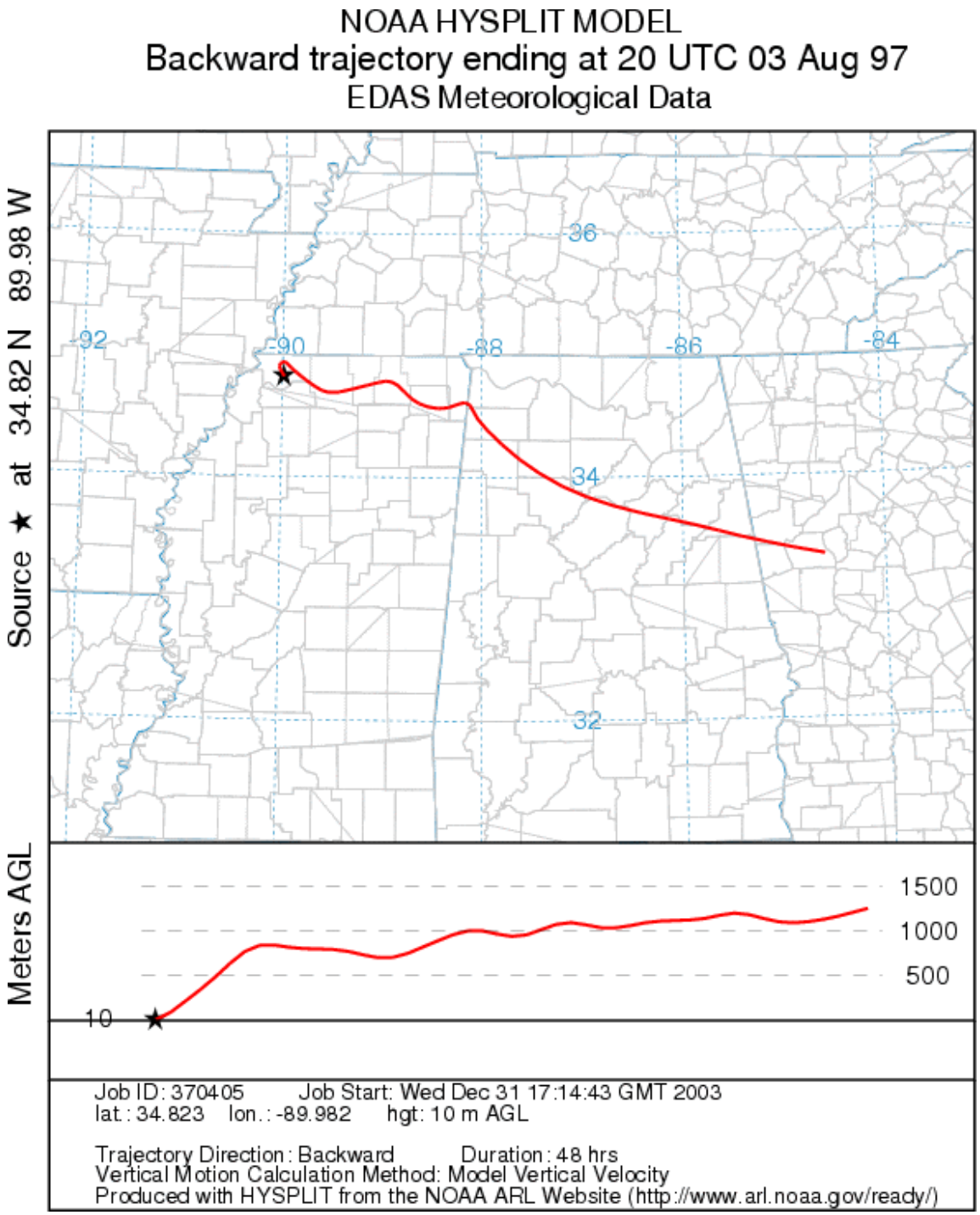
Light southerly transport winds originating in central Mississippi and flowing through northwestern Mississippi before arriving at the E. O. Park ozone monitor.

Hernando, Mississippi Monitor 48-Hour Back Trajectory for the Period Ending July 20, 1997
Maximum 8-Hour Average – 108 ppb – 1st Max



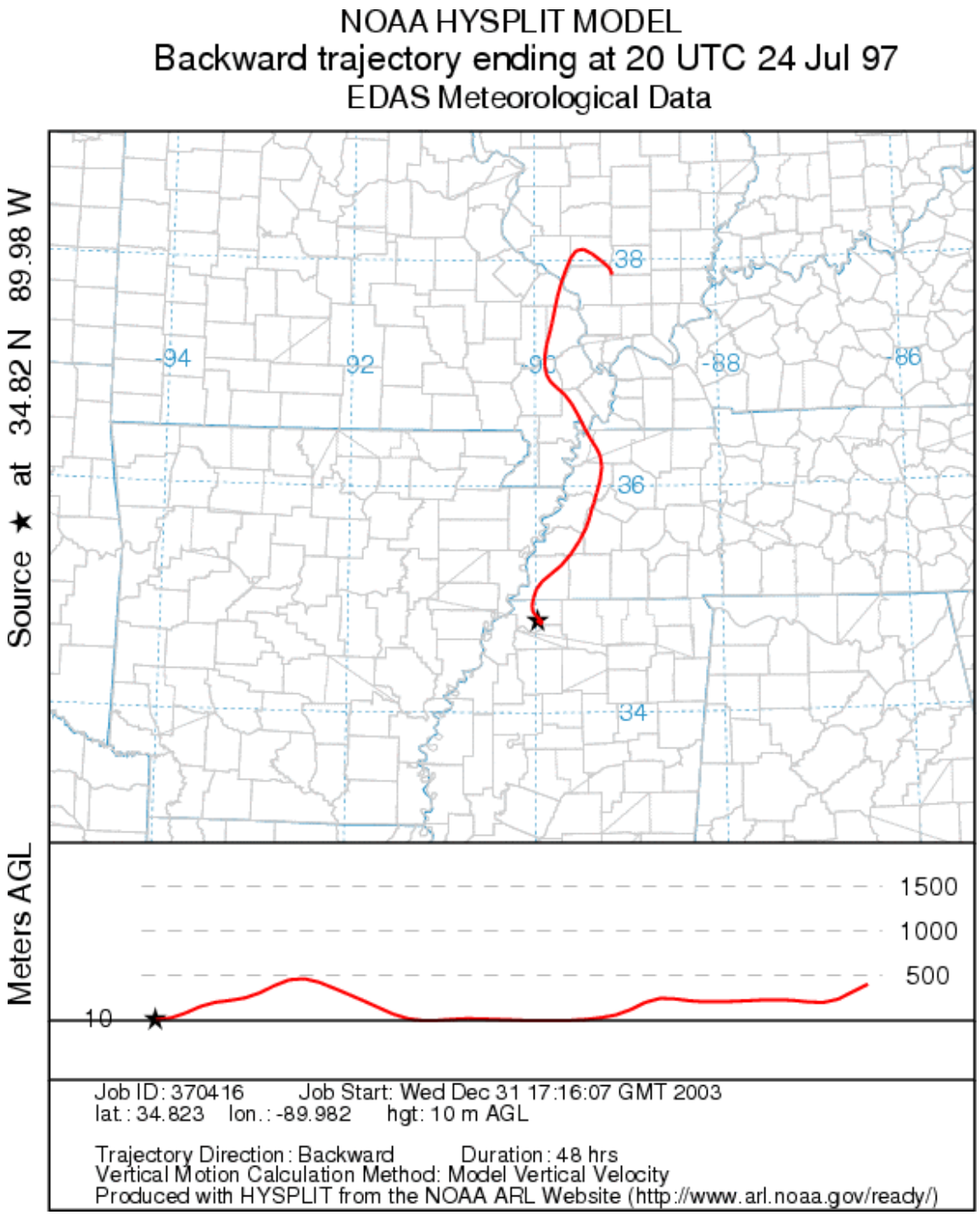
Moderate westerly transport winds originating in east central Missouri and flowing through southern Illinois becoming northerly through western Kentucky and western Tennessee before arriving at the Hernando ozone monitor.

Hernando, Mississippi Monitor 48-Hour Back Trajectory for the Period Ending August 3, 1997
Maximum 8-Hour Average – 99 ppb – 2nd Max



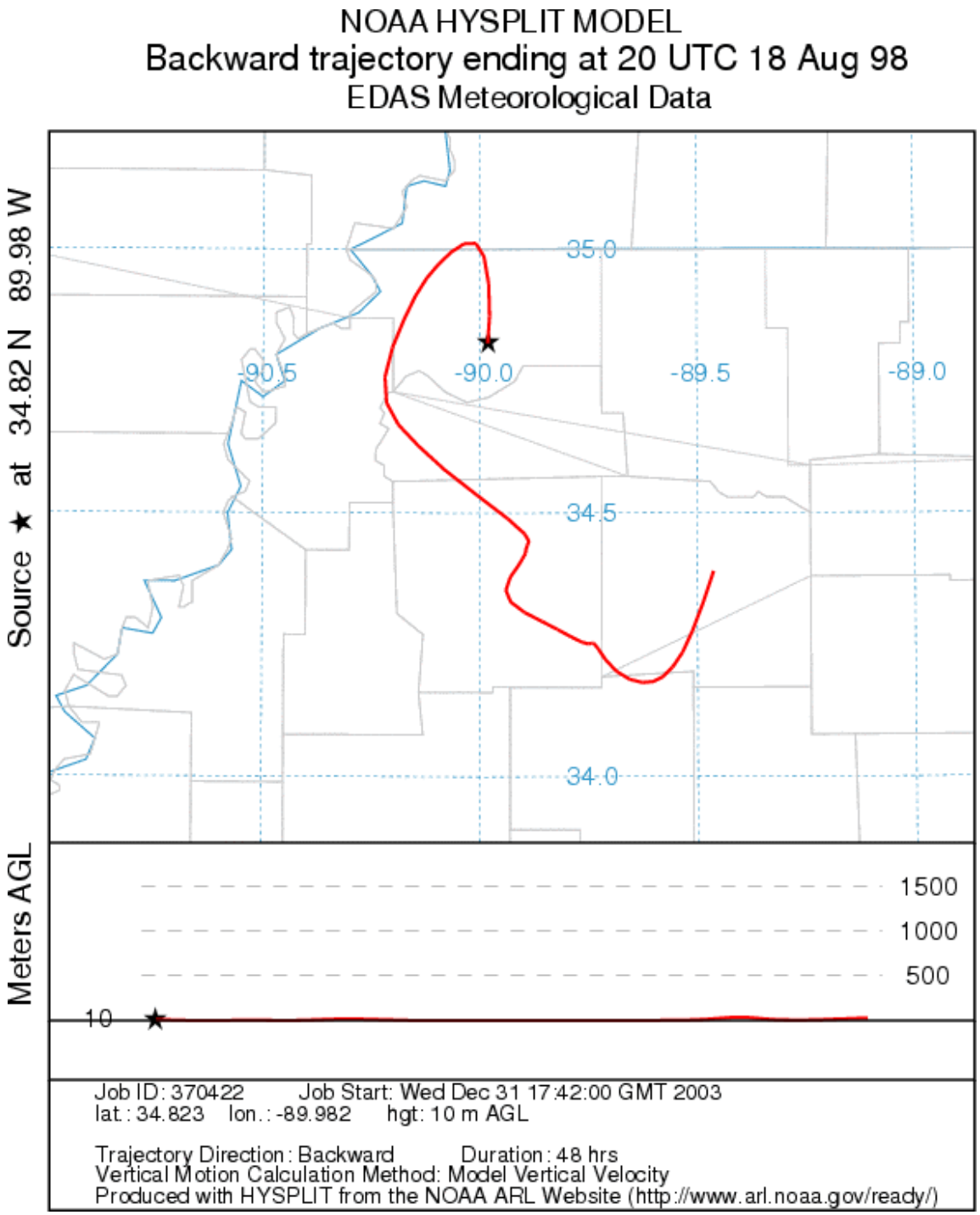
Moderate southeasterly transport winds originating in western Georgia and flowing through northern Alabama and northern Mississippi before arriving at the Hernando ozone monitor.

Hernando, Mississippi Monitor 48-Hour Back Trajectory for the Period Ending July 24, 1997
Maximum 8-Hour Average – 86 ppb – 3rd Max



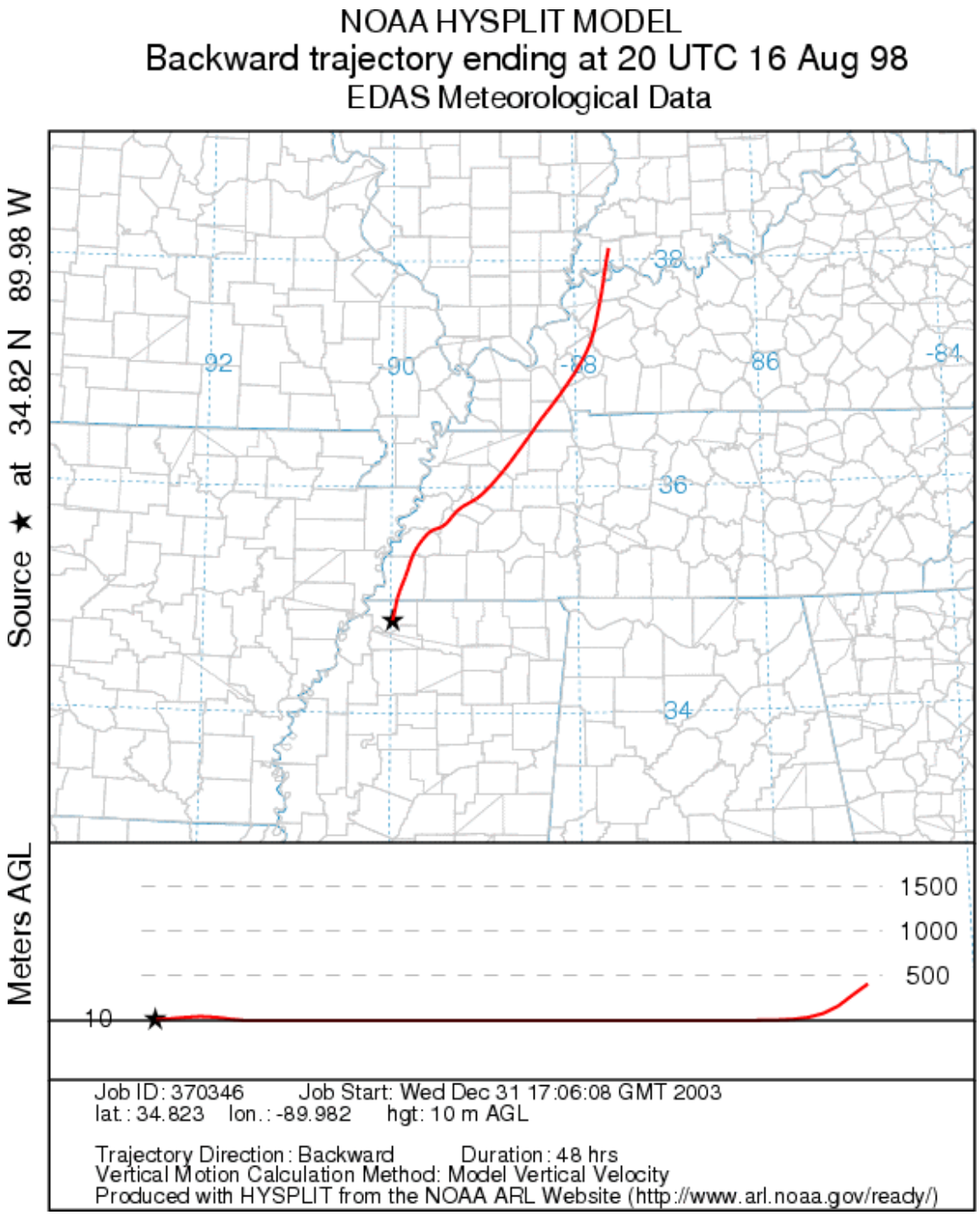
Moderate northerly transport winds originating in southern Illinois and flowing through southeastern Missouri and western Tennessee before arriving at the Hernando ozone monitor.

Hernando, Mississippi Monitor 48-Hour Back Trajectory for the Period Ending August 18, 1998
Maximum 8-Hour Average – 99 ppb – 1st Max



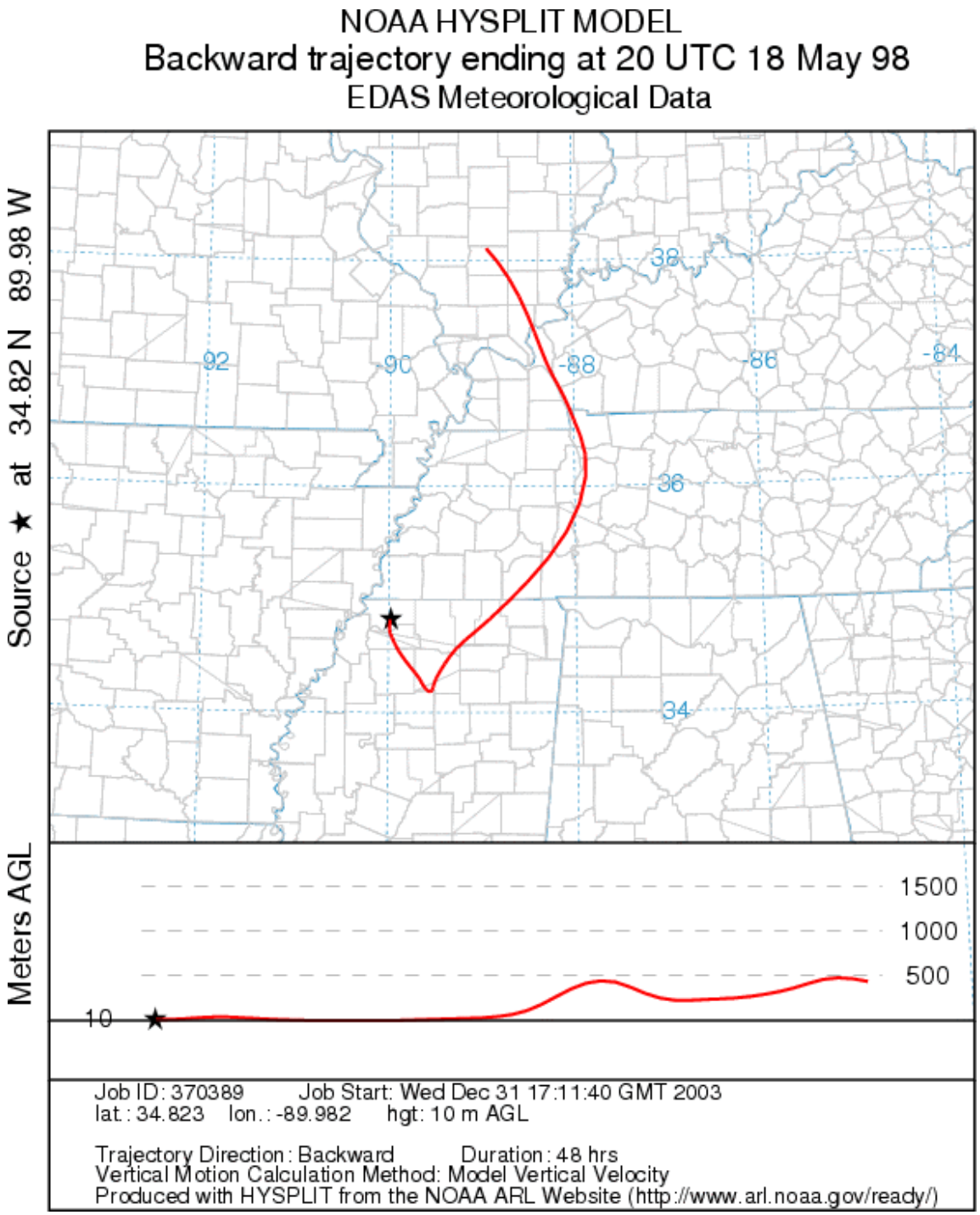
Light and variable transport winds flowing through northwestern Mississippi before arriving at the Hernando ozone monitor.

Hernando, Mississippi Monitor 48-Hour Back Trajectory for the Period Ending August 16, 1998
Maximum 8-Hour Average – 96 ppb – 2nd Max



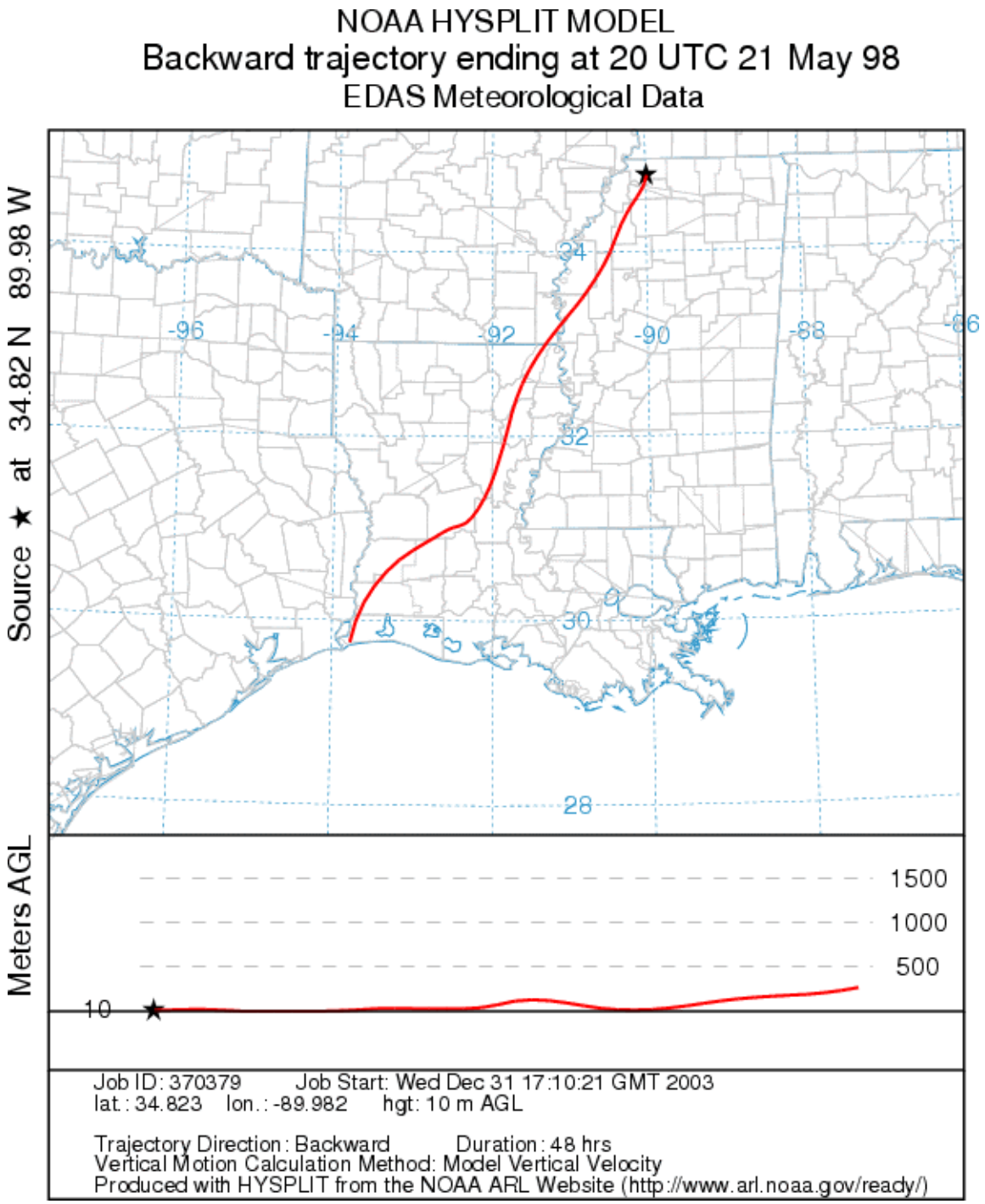
Moderate northeasterly transport winds originating in southwestern Indiana and flowing through western Kentucky and western Tennessee before arriving at the Hernando ozone monitor.

Hernando, Mississippi Monitor 48-Hour Back Trajectory for the Period Ending May 18, 1998
Maximum 8-Hour Average – 95 ppb – 3rd Max



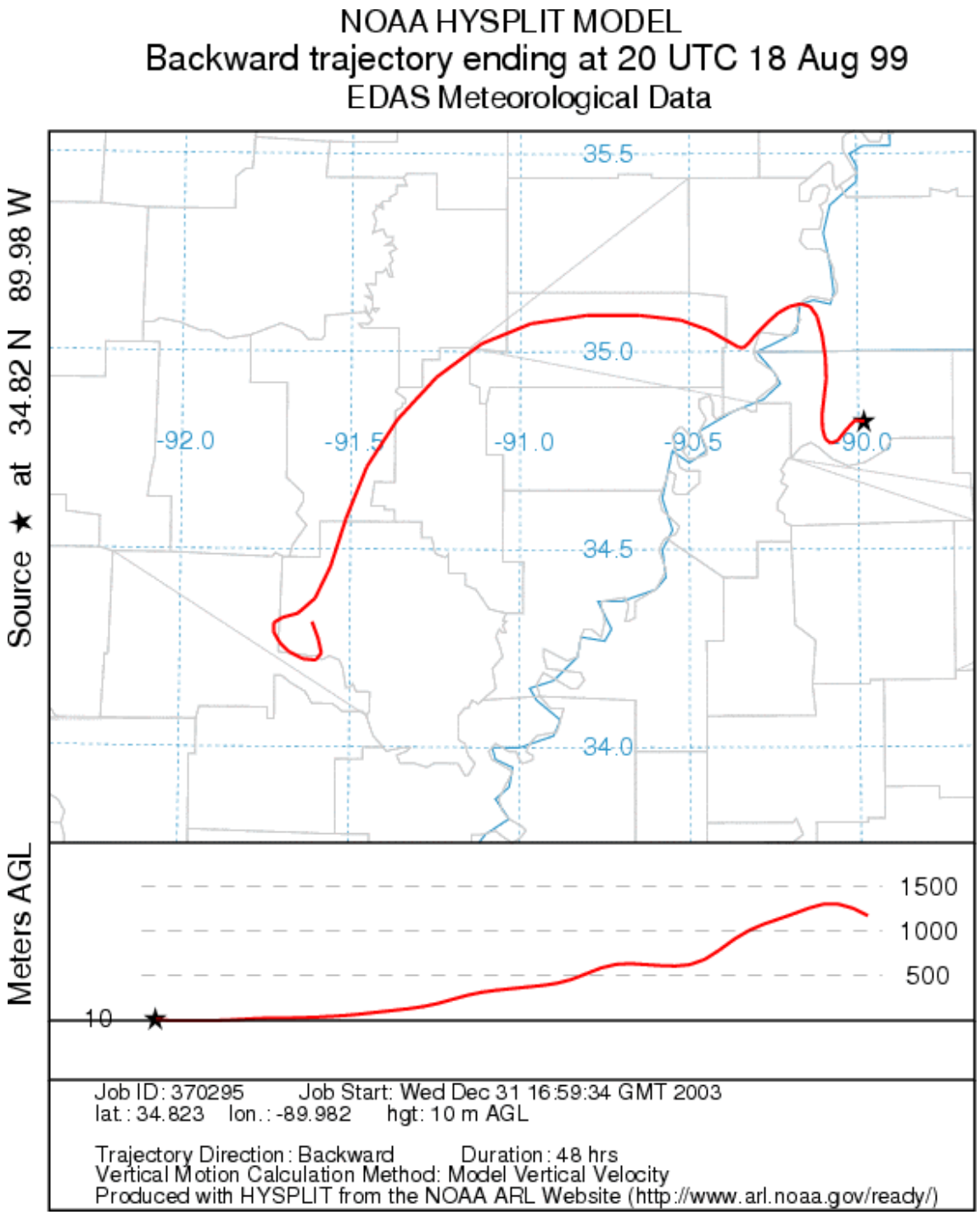
Moderate northerly transport winds originating in southern Illinois and flowing through western Kentucky, western Tennessee, and northern Mississippi before arriving at the Hernando ozone monitor.

Hernando, Mississippi Monitor 48-Hour Back Trajectory for the Period Ending May 21, 1998
Maximum 8-Hour Average – 89 ppb – 4th Max



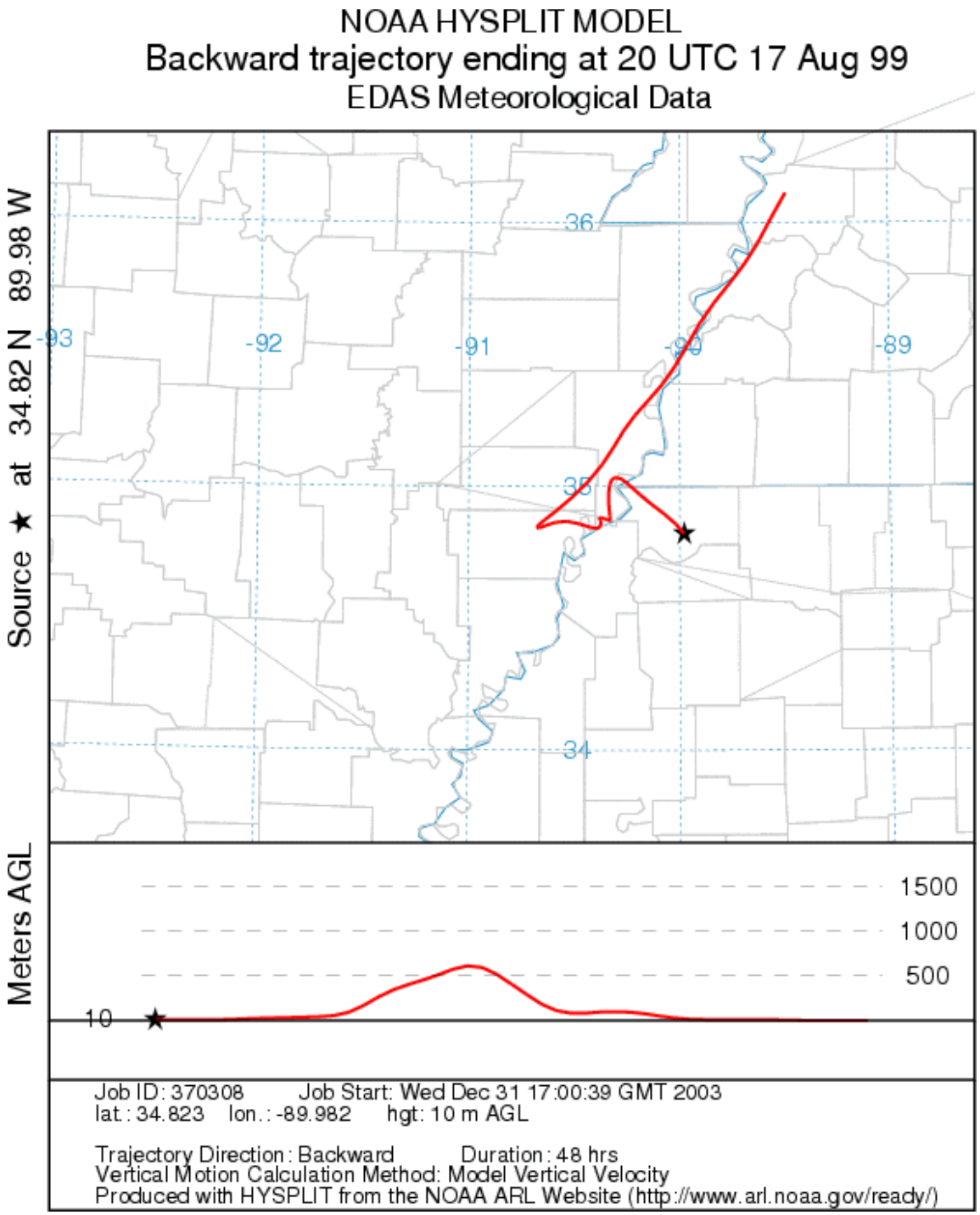
Moderate southwesterly transport winds originating in southwest Louisiana and flowing through Louisiana and northwestern Mississippi before arriving at Hernando ozone monitor.

Hernando, Mississippi Monitor 48-Hour Back Trajectory for the Period Ending August 18, 1999
Maximum 8-Hour Average – 108 ppb – 1st Max



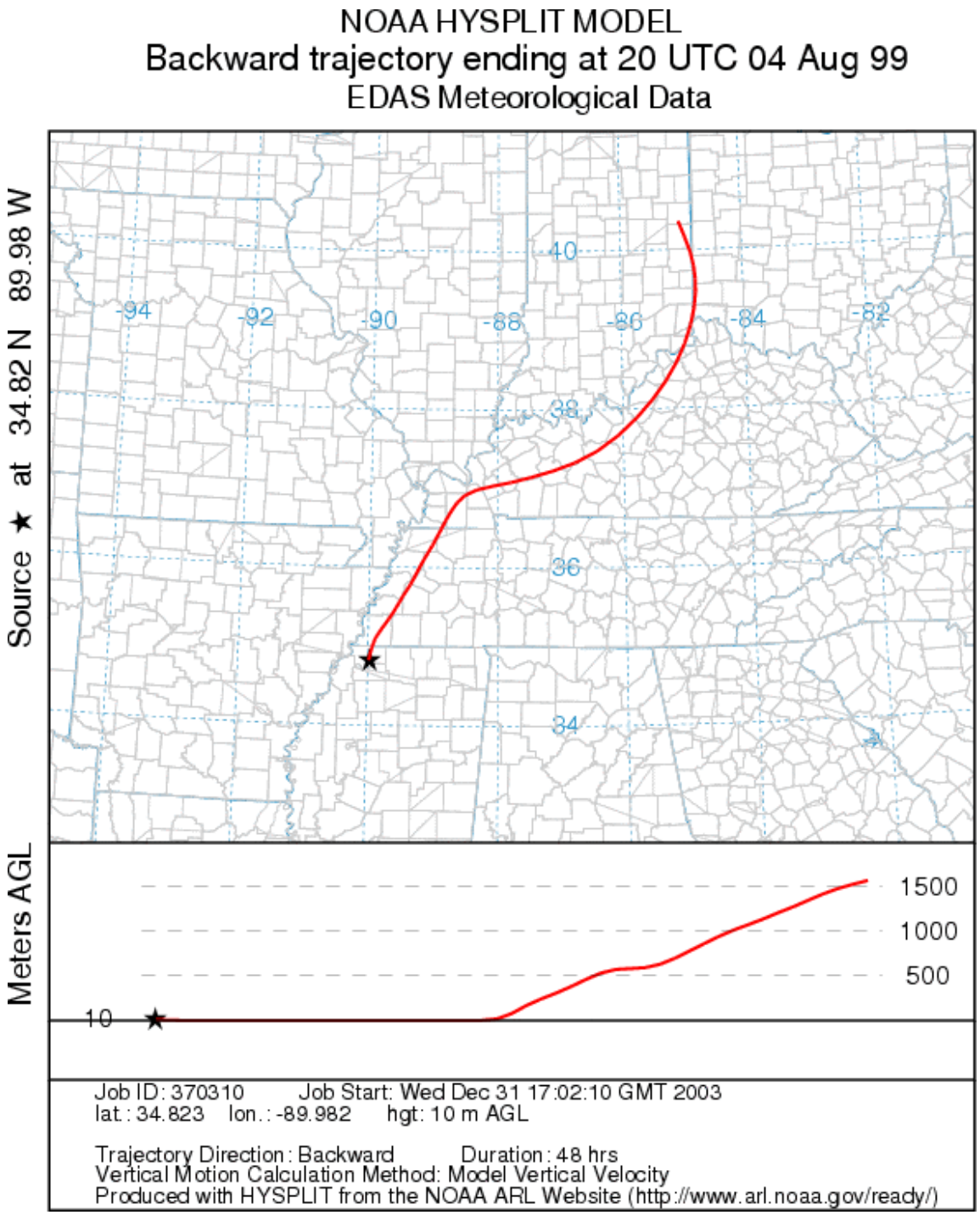
Light and variable transport winds flowing through eastern Arkansas before arriving at the Hernando ozone monitor.

Hernando, Mississippi Monitor 48-Hour Back Trajectory for the Period Ending August 17, 1999
Maximum 8-Hour Average – 100 ppb – 2nd Max



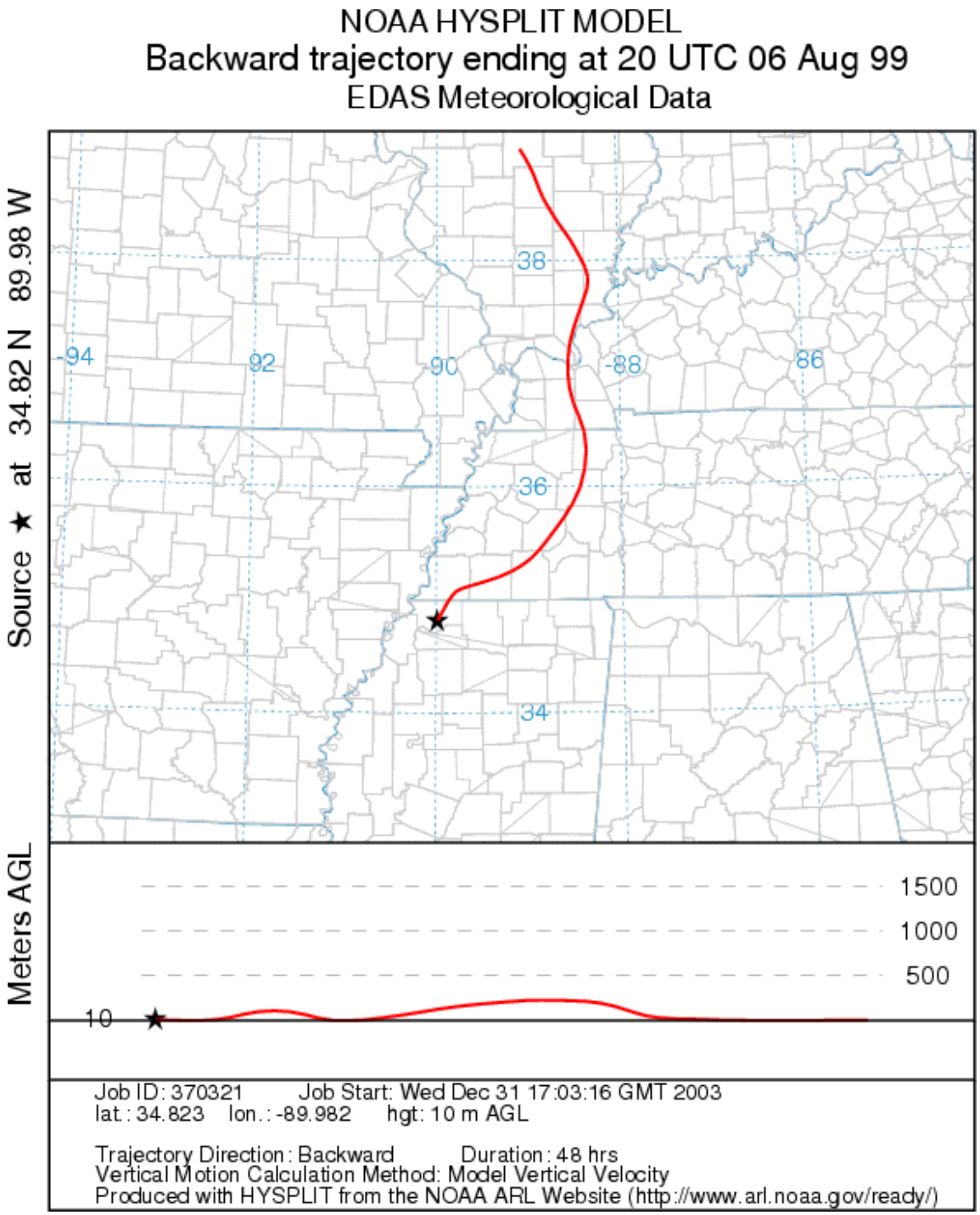
Light northeasterly transport winds originating in northwestern Tennessee and flowing through eastern Arkansas before arriving at the Hernando ozone monitor.

Hernando, Mississippi Monitor 48-Hour Back Trajectory for the Period Ending August 4, 1999
Maximum 8-Hour Average – 97 ppb – 3rd Max



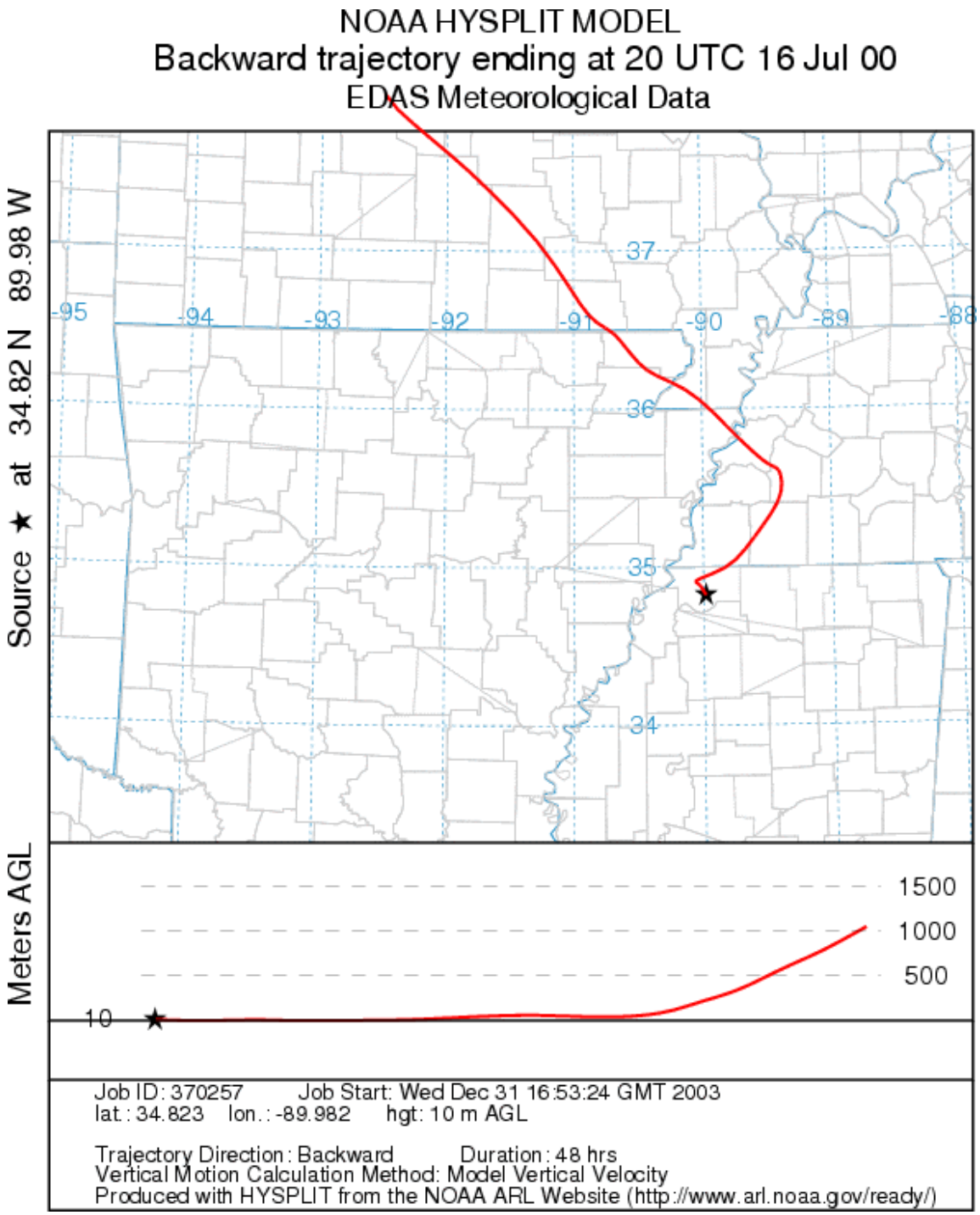
Moderate northeasterly transport winds originating in eastern Indiana and flowing through Kentucky and western Tennessee before arriving at the Hernando ozone monitor.

Hernando, Mississippi Monitor 48-Hour Back Trajectory for the Period Ending August 6, 1999
Maximum 8-Hour Average – 93 ppb – 4th Max



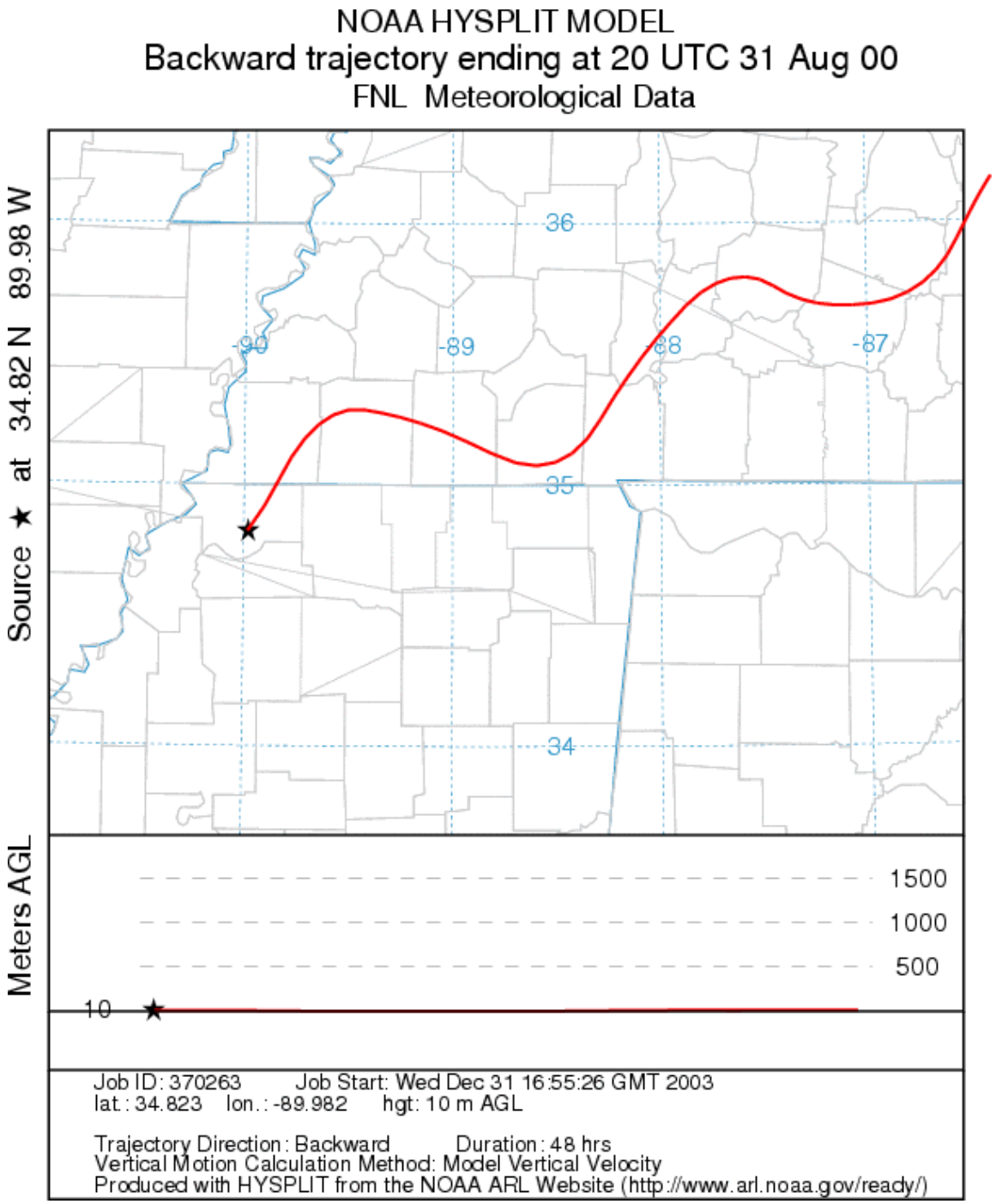
Moderate northerly transport winds originating in southern Illinois and flowing through western Kentucky and western Tennessee before arriving at the Hernando ozone monitor.

Hernando, Mississippi Monitor 48-Hour Back Trajectory for the Period Ending July 16, 2000
Maximum 8-Hour Average – 96 ppb – 1st Max



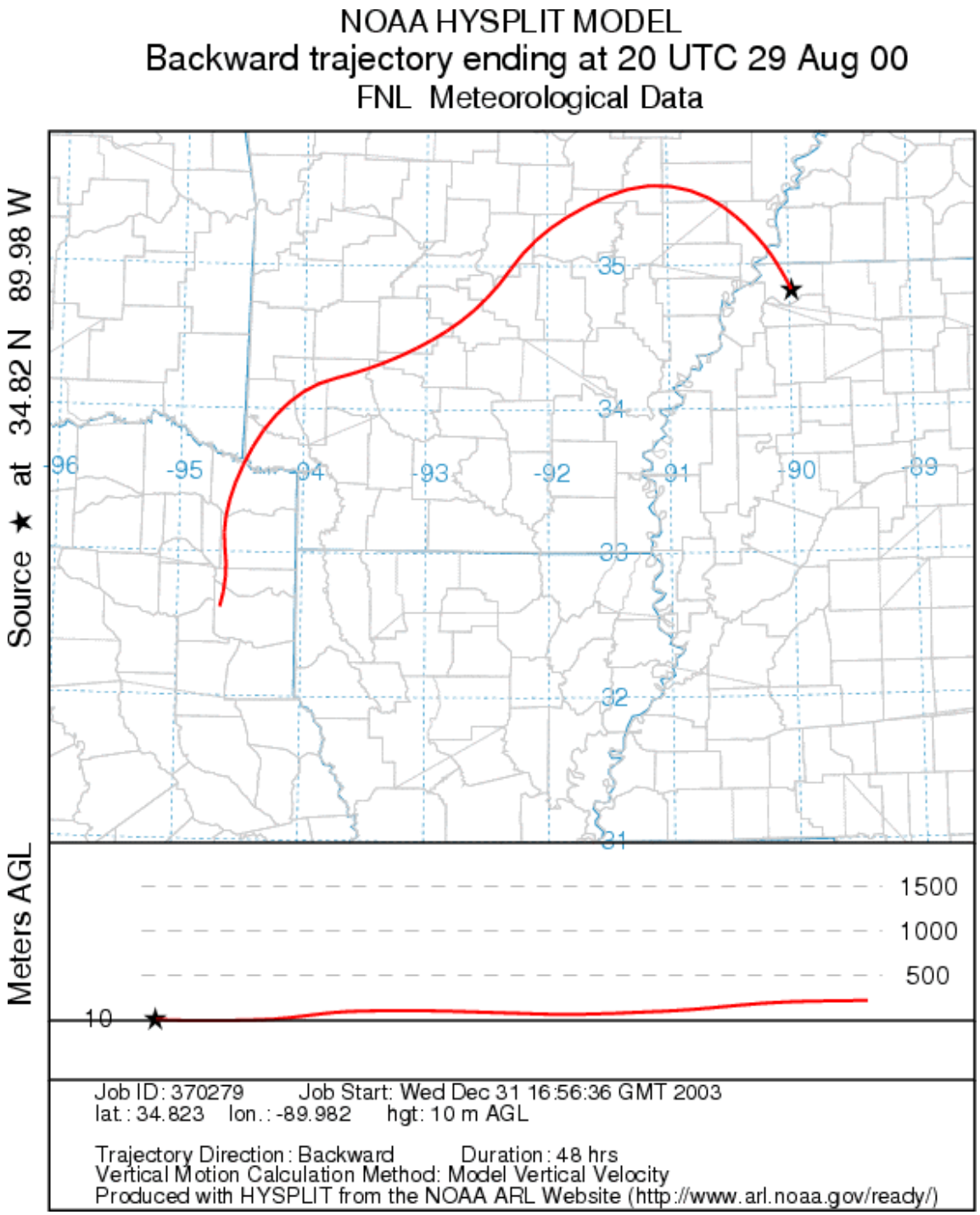
Light northwesterly transport winds originating in central Missouri and flowing through northeastern Arkansas and western Tennessee before arriving at the Hernando ozone monitor.

Hernando, Mississippi Monitor 48-Hour Back Trajectory for the Period Ending August 31, 2000
Maximum 8-Hour Average – 95 ppb – 2nd Max



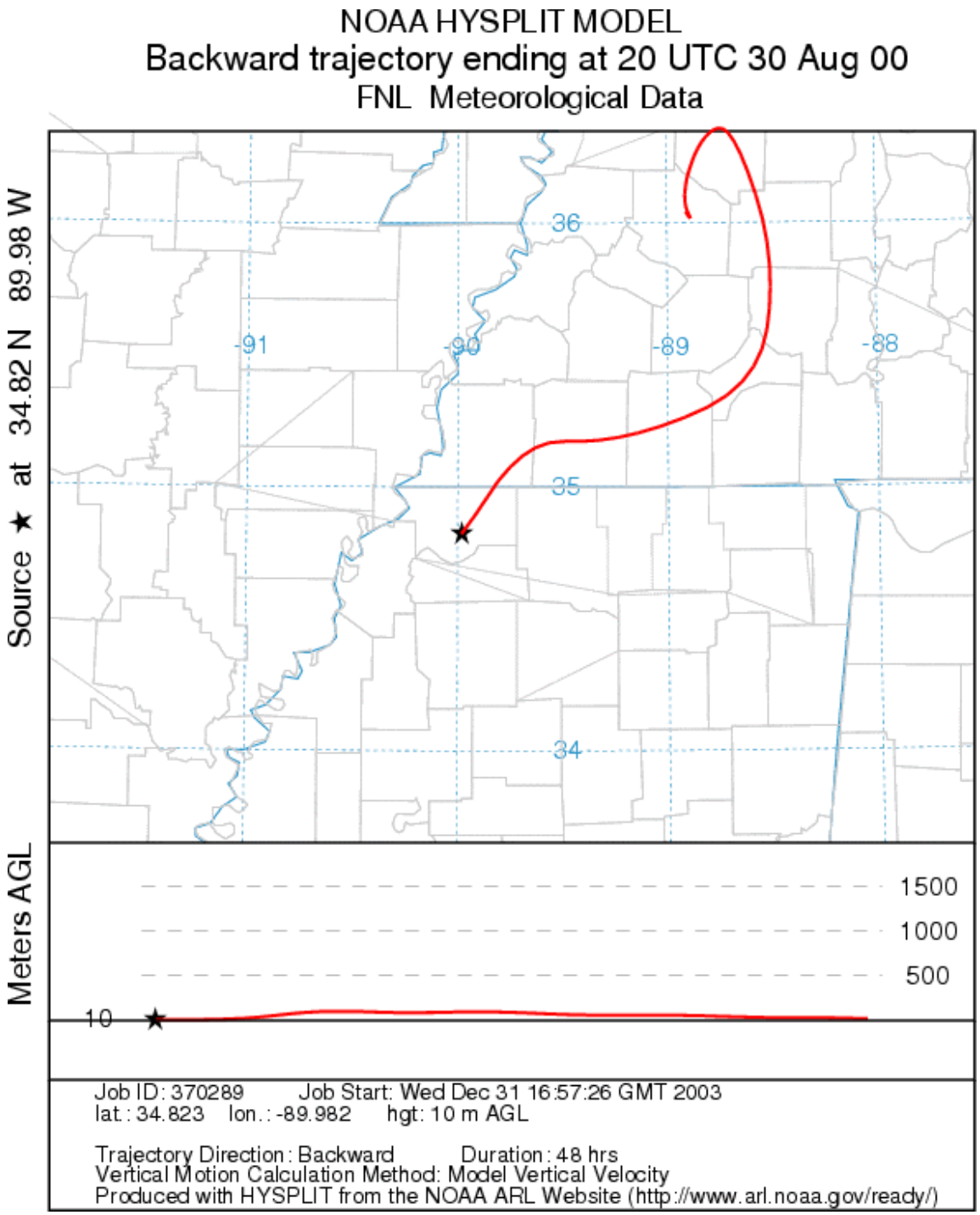
Light and variable transport winds originating in central Tennessee and flowing through western Tennessee before arriving at the Hernando ozone monitor.

Hernando, Mississippi Monitor 48-Hour Back Trajectory for the Period Ending August 29, 2000
Maximum 8-Hour Average – 92 ppb – 3rd Max



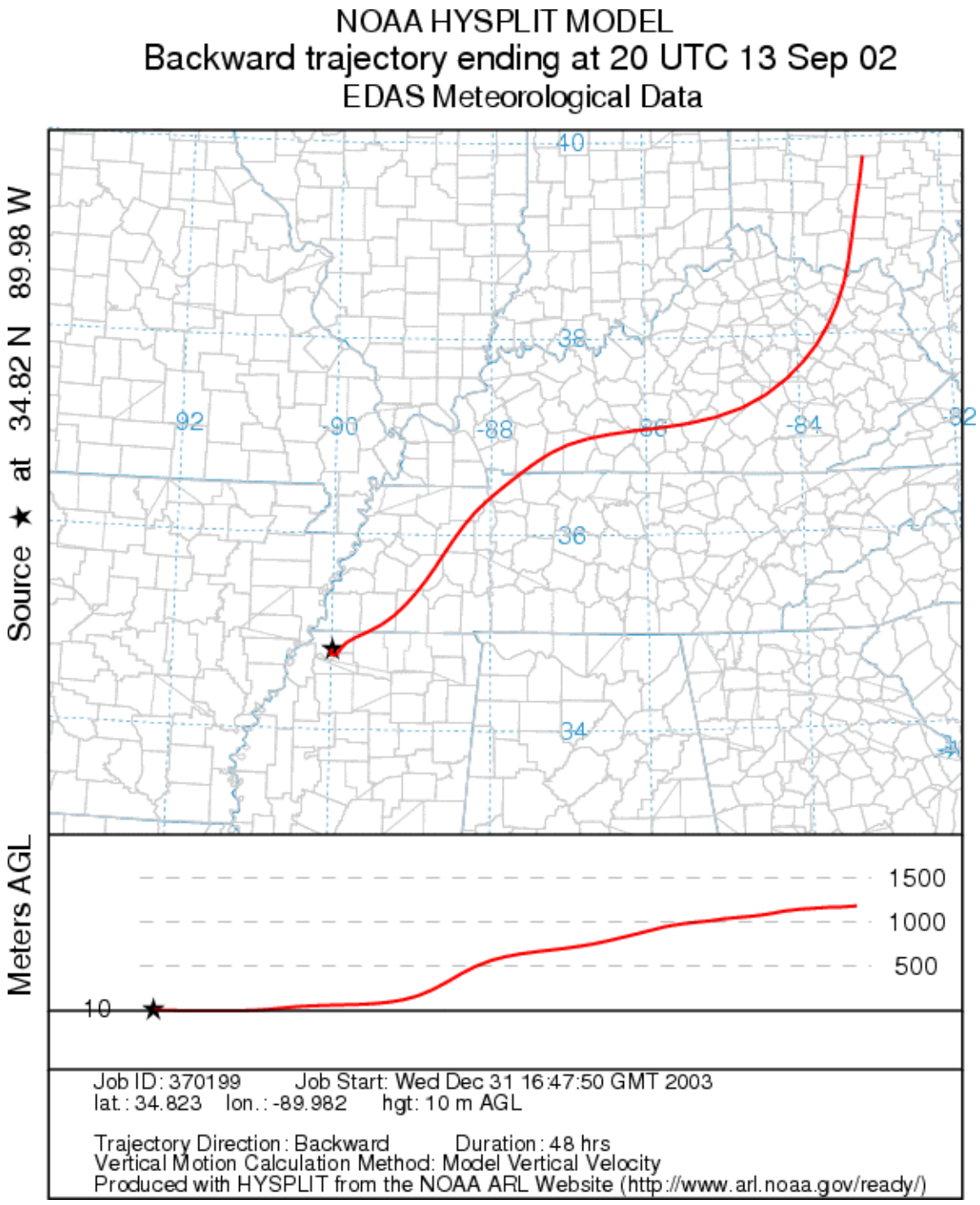
Moderate southerly transport winds originating in northeastern Texas becoming westerly while flowing through central Arkansas before arriving at the Hernando ozone monitor.

Hernando, Mississippi Monitor 48-Hour Back Trajectory for the Period Ending August 30, 2000
Maximum 8-Hour Average – 92 ppb – 4th Max



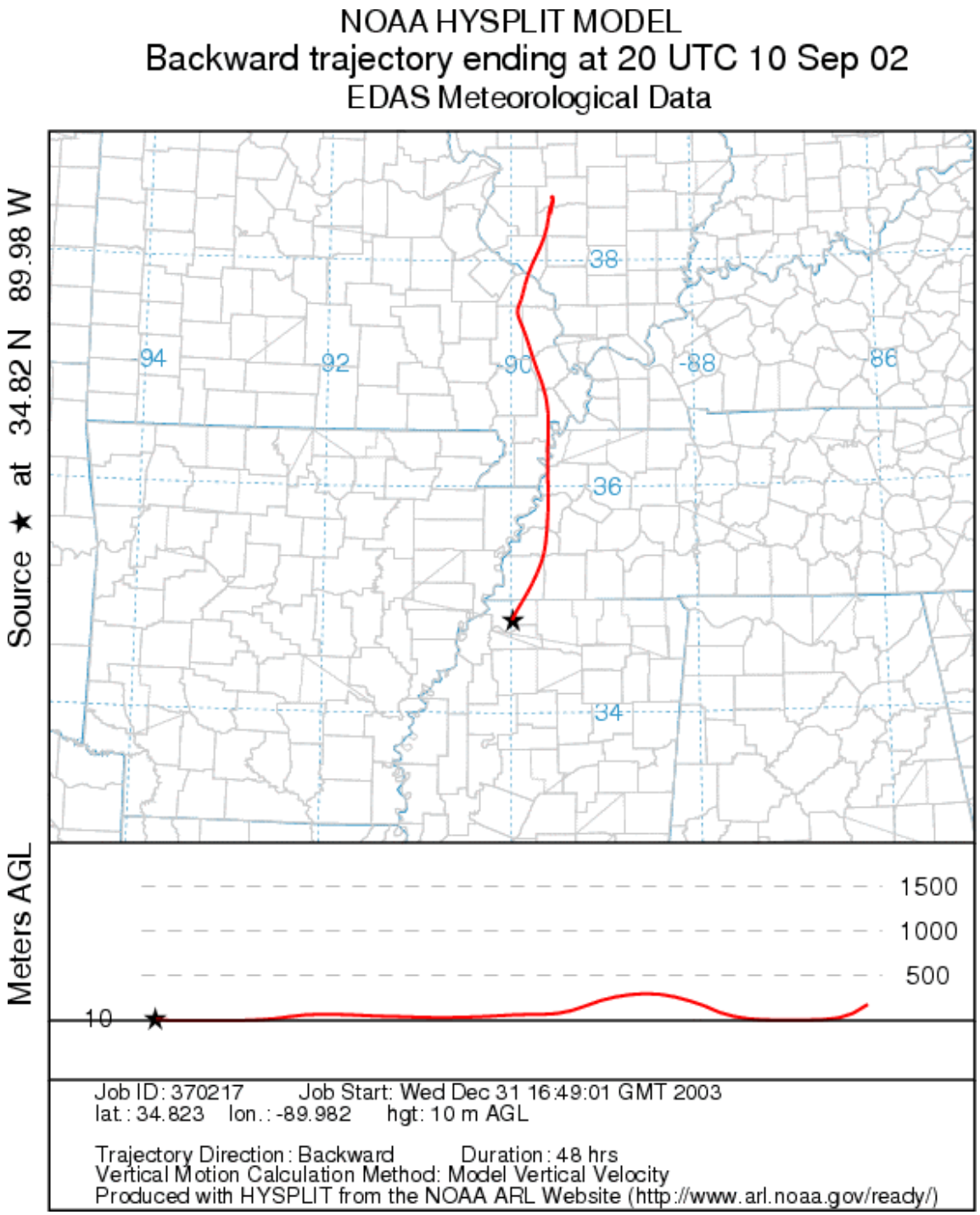
Light and variable transport winds flowing through western Tennessee before arriving at the Hernando ozone monitor.

Hernando, Mississippi Monitor 48-Hour Back Trajectory for the Period Ending September 13, 2002
Maximum 8-Hour Average – 103 ppb – 1st Max



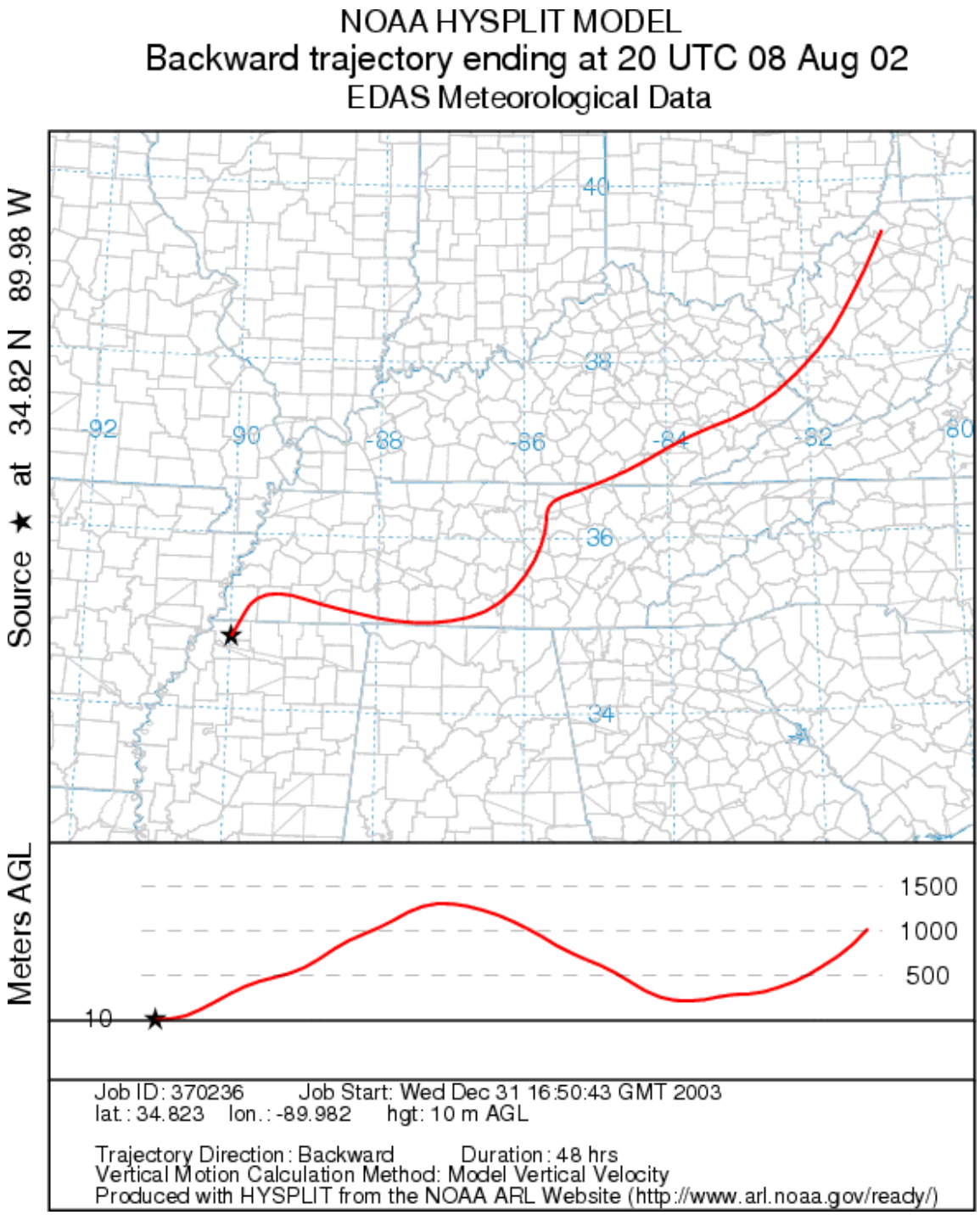
Moderate northerly transport winds originating in central Ohio and flowing through eastern Kentucky becoming northeasterly in southern Kentucky and western Tennessee before arriving at the Hernando ozone monitor.

Hernando, Mississippi Monitor 48-Hour Back Trajectory for the Period Ending September 10, 2002
Maximum 8-Hour Average – 102 ppb – 2nd Max



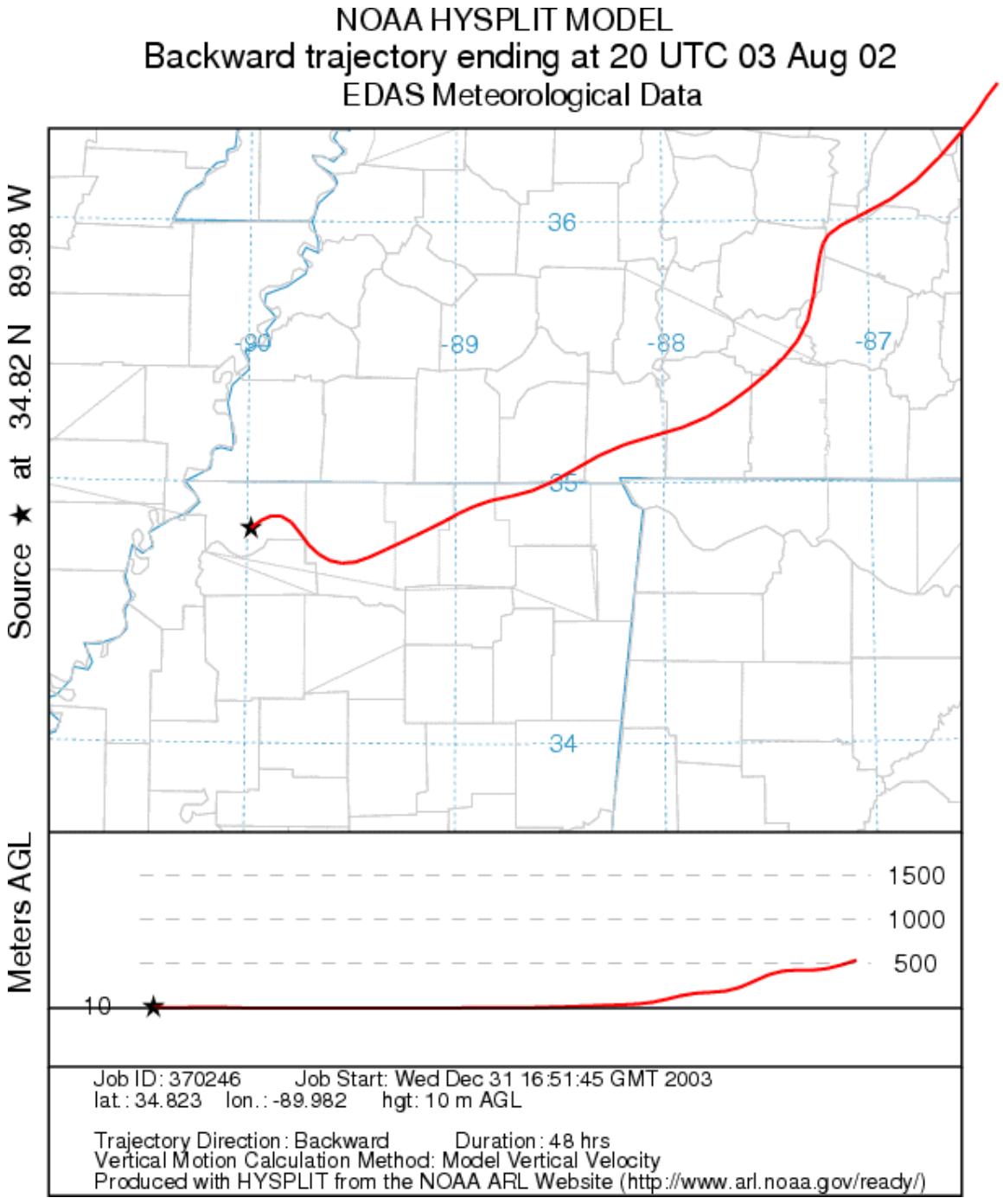
Moderate northerly transport winds originating in southern Illinois and flowing through southeastern Missouri and western Tennessee before arriving at the Hernando ozone monitor.

Hernando, Mississippi Monitor 48-Hour Back Trajectory for the Period Ending August 8, 2002
Maximum 8-Hour Average – 95 ppb – 3rd Max



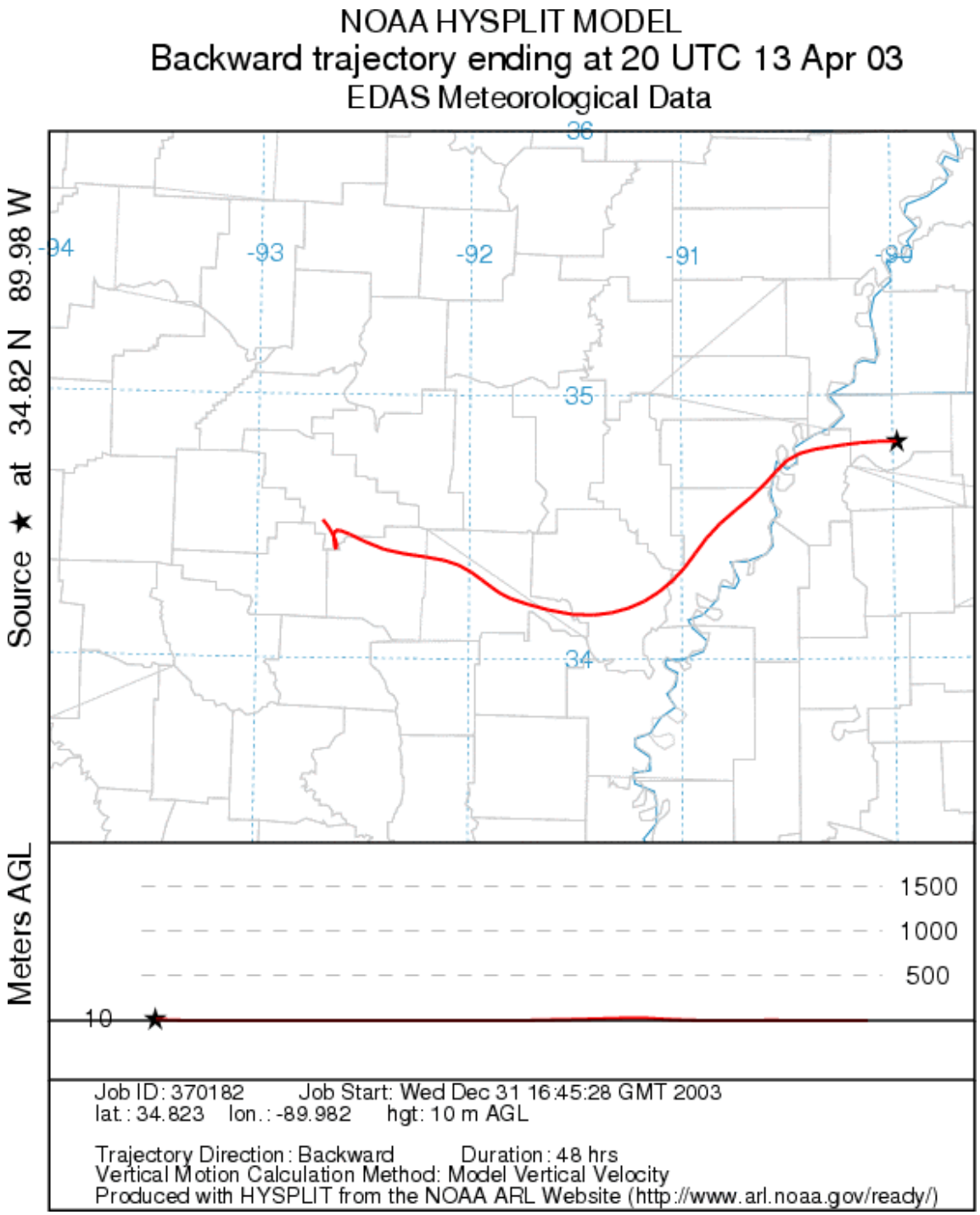
Moderate northeasterly transport winds originating in West Virginia and flowing through southeastern Kentucky and central and southern Tennessee before arriving at the Hernando ozone monitor.

Hernando, Mississippi Monitor 48-Hour Back Trajectory for the Period Ending August 3, 2002
Maximum 8-Hour Average – 91 ppb – 4th Max



Light northeasterly transport winds originating in central Tennessee and flowing through northern Mississippi before arriving at the Hernando ozone monitor.

Hernando, Mississippi Monitor 48-Hour Back Trajectory for the Period Ending April 13, 2003
Maximum 8-Hour Average – 86 ppb – 1st Max



Light and variable transport winds flowing through central Arkansas before arriving at the Hernando ozone monitor.

Population and Growth Data for the Memphis MSA

Part of MSA	1990 Census	2000 Census	Increase
DeSoto County,MS	67,910	107,199	39,289
Shelby County,TN	826,330	896,013	69,683
Fayette County, TN	25,559	28,806	3,247
Tipton County, TN	37,568	51,271	13,703
Crittenden County, AR	49,939	50,866	927
Total	1,007,306	1,134,155	126,849

Source: U.S. Census Bureau