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New Technology Research & Development Program
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Tasks 1, 2, 3, & 4 Deliverable Report
Final Report – Appendix 1

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by the State of Texas through a Grant from the
Texas Commission on Environmental Quality.

Back-Trajectory Analyses on High and Low Ozone Days for the Dallas/Fort Worth and Houston/Galveston/Brazoria Ozone Nonattainment Areas for the Years 2001 through 2005

Prepared for
Texas Commission on Environmental Quality
New Technology Research & Development (NTRD) Program
Contract Number: 582-5-65591-0003

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October 19, 2006

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October 19, 2006

Executive Summary

This report provides the results of back-trajectory analyses (using data for the years 2001 through 2005) performed for the Dallas/Fort Worth (DFW) and Houston/Galveston/Brazoria (HGB) ozone nonattainment areas using the National Oceanic and Atmospheric Administration's HYbrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) application. The primary goal of this project was to generate residence time contour maps that visually summarize the most frequent geographic areas upwind of the DFW and HGB areas prior to days when high ozone concentrations were measured (high ozone days) and prior to days when low ozone concentrations were measured (low ozone days) grouped by month. This report provides a description of the methodology used to generate the residence time contour maps and presents the results.

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1.0 Introduction

This report provides the results of back-trajectory analyses performed for the Dallas/Fort Worth (DFW) and Houston/Galveston/Brazoria (HGB) ozone nonattainment areas using the National Oceanic and Atmospheric Administration's HYbrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) application. Five-day (120-hour) back-trajectories were generated for all days during the months of April through October for the years 2001 through 2005. The five-day trajectory duration was selected to capture long-range transport not only within Texas, but also from distant areas, such as the central and southeastern US, during conditions of relatively low wind speeds in the lower atmosphere. The primary goal of this project was to generate residence time contour maps that visually summarize the most frequent geographic areas upwind of the DFW and HGB areas prior to days characterized by high and low ozone concentrations averaged over 8 hours. These geographic areas would correspond to the potential source regions of background ozone entering each area. The use of an ensemble of back-trajectories provides a more robust analysis than that obtained with individual back-trajectories. The generation of monthly maps provides for a comparison of the seasonal differences in long-range transport patterns. The maps also allow for an intercomparison of the spatial variability in upwind geographic areas between the DFW and HGA areas.

A similar analysis has been performed for the Texas ozone near nonattainment areas of Austin, Corpus Christi, San Antonio, Tyler/Longview/Marshall, and Victoria. The results of these analyses were originally provided to TCEQ and each NNA via a MicroSoft Powerpoint presentation data August 1, 2006 and entitled "Residence Time Maps using Daily 120-Hour Back-Trajectories for High and Low Ozone Days in the Near-Nonattainment Areas (NNAs)". A full report for the project was provided to The City of Victoria and the Texas Commission on Environmental Quality (TCEQ) in October 2006 (UT, 2006).

The primary goal of this report is to document the datasets and methodology used to generate the residence time contour maps for DFW and HGB. A description of the datasets is provided in Section 2.0. Section 3.0 provides a summary of the methodology and software developed to generate the maps. Section 4.0 provides a brief description of the results. Recommendations for further study and references are provided in Section 5.0 and Section 6.0, respectively. The residence time contour maps are provided in Appendices A and B for the DFW and HGB areas, respectively.

2.0 Data

The ozone regional transport analyses for the DFW and HGB ozone nonattainment areas were based on historical ozone and meteorological conditions that occurred during the months of April through October for the years 2001 through 2005. The ozone concentration measurement data were collected at Community Air Monitoring Stations (CAMS) provided to The University of Texas Center for Energy and Environmental Resources (UT/CEER) by TCEQ staff. The back-trajectories were calculated using the NOAA HYSPLIT model and three-dimensional wind speed and wind direction data archived by Air Resources Laboratory (ARL).

2.1 Ozone measurements

Daily maximum ozone concentrations averaged over 8 hours were utilized for the analyses presented in this report. The daily maximum ozone concentrations collected at CAMS located throughout the State of Texas were received from Zhaohua Fang (TCEQ) by Dave Sullivan (UT/CEER) on June 15, 2006 in MicroSoft Excel format. TCEQ retrieved these data from EPA's Air Quality System (AQS) database following the submittal of these data to EPA by TCEQ's Monitoring Operations Division. The retrieval of these data from EPA guarantees that the ozone data have been verified following the AQS quality assurance procedures.

A summary of the identification data for the DFW and HGB CAMS included in the analyses presented in this report are provided in Table 2-1 and Table 2-2, respectively. All available monitoring data were utilized regardless of the overall data completeness with respect to ozone measurements at each monitoring station during the years 2001 through 2005. Geographic maps showing the locations of the monitoring stations are available from the TCEQ website (http://www.tceq.state.tx.us/nav/data/aq_data.html).

Table 2-1. Description of Dallas/Fort Worth CAMS

CAMS	AIRS ID	Station Name	Address	Latitude (degrees)	Longitude (degrees)
31	480850005	Frisco	6590 Hillcrest Rd.	33.132	-96.786
68	480850010	Anna	817 N. Texas Highway 5	33.356	-96.551
401	481130069	Dallas Hinton St.	1415 Hinton St.	32.820	-96.860
63	481130075	Dallas North No.2	12532 1/2 Nuestra Dr.	32.919	-96.808
402	481130087	Dallas Executive Airport	3277 West Redbird Ln.	32.677	-96.872
74	481133003	Sunnyvale Long Creek	405 Long Creek Rd.	32.769	-96.546
56	481210034	Denton Airport South	Denton Municipal Airport	33.194	-97.193
94	481390015	Midlothian Tower	4252 Waterworks Rd.	32.437	-97.024
77	482510003	Cleburne Airport	1650 Airport Dr.	32.353	-97.437
71	482570005	Kaufman	3790 S. Houston St.	32.565	-96.318
76	483670081	Parker County	3033 New Authon Rd.	32.869	-97.906
69	483970001	Rockwall Heath	100 East Heath St.	32.936	-96.459
75	484390075	Eagle Mountain Lake	14290 Morris Dido Newark Rd.	32.988	-97.477
13	484391002	Ft. Worth Northwest	3317 Ross Ave	32.806	-97.356
17	484392003	Keller	Alta Vista Rd.	32.923	-97.282
70	484393009	Grapevine Fairway	4100 Fairway Dr.	32.984	-97.064
61	484393011	Arlington Municipal Airport	5504 South Collins St.	32.656	-97.088
			Average	**32.846**	**-97.002**

Table 2-2. Description of Houston/Galveston/Brazoria CAMS

CAMS	AIRS ID	Station Name	Address	Latitude (degrees)	Longitude (degrees)
11	480391003	Clute	426 Commerce St.	29.011	-95.398
84	480391004	Manvel Croix Park	4503 Croix Parkway	29.520	-95.393
1016	480391016	Lake Jackson	109-B Brazoria Hwy 332-W	29.044	-95.473
34	481670014	Galveston Airport	8715 Cessna St.	29.263	-94.856
10	481671002	Texas City	2700 1/2 13th Avenue North	29.398	-94.933
8	482010024	Houston Aldine	4510 1/2 Aldine Mail Rd.	29.901	-95.326
15	482010026	Channelview	1405 Sheldon Rd.	29.803	-95.126
26	482010029	Northwest Harris Co.	16822 Kitzman St.	30.039	-95.674
405	482010046	Houston North Wayside	7330 1/2 N.Wayside	29.828	-95.284
408	482010047	Lang	4401 1/2 Lang	29.834	-95.489
409	482010051	Houston Croquet	13826 1/2 Croquet	29.624	-95.474
53	482010055	Houston Bayland Park	6400 Bissonnet St.	29.696	-95.499
406	482010062	Houston Monroe	9726 1/2 Monroe	29.626	-95.267
410	482010066	Houston Westhollow	3333 1/2 Highway 6	29.723	-95.636
81	482010070	Houston Regional Office	5425 Polk Ave	29.735	-95.316
411	482010075	Houston Texas Avenue	2311 Texas Ave	29.753	-95.350
1015	482011015	Lynchburg Ferry	1001 B Lynchburg Rd.	29.764	-95.078
1	482011034	Houston East	1262 1/2 Mae Dr.	29.768	-95.221
403	482011035	Clinton	9525 1/2 Clinton Dr.	29.734	-95.258
35	482011039	Houston Deer Park 2	4514 1/2 Durant St.	29.670	-95.128
45	482011050	Seabrook Friendship Park	4522 Park Rd.	29.583	-95.015
78	483390078	Conroe Relocated	9472A Highway 1484	30.350	-95.425
			Average	**29.667**	**-95.301**

2.2 HYSPLIT Back-Trajectories

The Lagrangian trajectory HYSPLIT model was used to investigate the potential geographic source regions of air entering the DFW and HGB areas. HYSPLIT was developed by a joint effort between the National Oceanic and Atmospheric Administration (NOAA) and Australia's Bureau of Meteorology, and can be run interactively on the World Wide Web (http://www.arl.noaa.gov/ready/hysplit4.html). The model can calculate trajectories either forward or backward in time. Hourly trajectory positions are calculated using a gridded three-dimensional meteorological data set. The trajectories are generated from the position of a particle calculated as the average of the three-dimensional velocity vectors at the initial position and at the first guess of the next position. The velocity vectors from the input meteorological data set are linearly interpolated in space and time. Complete documentation of the calculation methodology can be accessed at the HYSPLIT website (http://www.arl.noaa.gov/ready/hysplit4.html).

2.3 Meteorological Data

HYSPLIT uses meteorological model forecast data from the National Centers for Environmental Prediction (NCEP) archived by Air Resources Laboratory (ARL). Back-trajectories for the 2001 through 2003 period were calculated using the three-dimensional wind field provided by the Eta Data Assimilation System (EDAS) at an 80-km horizontal resolution. Beginning in 2004, the EDAS is available at a 40-km horizontal resolution. Back-trajectories for the years 2004 and 2005 were calculated using the 40-km resolution dataset.

The EDAS meteorological fields are generated by NCEP using successive 3-hour Eta model forecasts and a three-dimensional objective data assimilation analysis technique. The data assimilation technique is essentially an optimized interpolation scheme that uses the Eta forecast model to merge and spatially interpolate routinely collected meteorological observational data. These meteorological observations include, for example, measurements collected at NOAA wind profiler stations, National Weather Service NEXRAD radars, and various aircraft platforms. NCEP operates EDAS on a 32-km horizontal grid on a terrain-following, vertical-coordinate system with 45 levels. The results of the successive 3-hour analyses are interpolated to a Lambert Conformal Grid and archived by ARL at 26 vertical levels. The data and documentation are available from the ARL web server (ftp://www.arl.noaa.gov/pub/archives).

3.0 Methodology

This section provides a description of the methodology used to generate the residence time contour maps provided in this report. A summary of the programming scripts and software developed by UT/CEER to perform the analyses is also provided.

3.1 Residence Time Maps

The primary goal of this project was to generate residence time contour maps that visually summarize the most frequent geographic areas upwind of the DFW and HG B ozone nonattainment areas prior to low and high ozone days. Each residence time map displays the frequency of occurrence of HYSPLIT back-trajectory hourly end points over a US geographic map. The maps were generated for each month during the April through October period using data collected during the years 2001 through 2005. The monthly maps provide a mechanism to compare and contrast the climatological seasonal variability in regional transport patterns. Maps were also generated for all days characterized by maximum ozone concentrations greater than 75 ppb and 85 ppb during the period.

3.2 Automation of HYSPLIT back-trajectories

The first step in generating the residence time maps required that five-day HYSPLIT back-trajectories be calculated for all days during the months of April through October for the years 2001 through 2005. A Tool Command Language (TCL) script ("auto_traj.tcl") was written by UT/CEER to automate the generation of the back-trajectories. The required three-dimensional meteorological EDAS datasets were downloaded directly from ARL (ftp://www.arl.noaa.gov/pub/archives). Back-trajectories were generated for the DFW and HGB areas using an initiation height of 500 meters above the surface. A back-trajectory starting height of 500 meters was selected as a representative height of the middle of the mixed layer during the late afternoon during ozone season across much of the eastern half of Texas. All back-trajectories were initiated at 5 p.m. Central Daylight Savings Time (CDT). The starting latitude and longitude was the average latitude and longitude of the monitoring locations used to determine the ozone conditions, as summarized for the DFW and HG B areas in Table 2-1 and Table 2-2, respectively. A total of 2140 individual back-trajectories (214 days * 5 years * 2 areas) were generated for the analyses presented in this report.

3.3 Merging of HYSPLIT back-trajectory hourly locations and ozone data

A MicroSoft Visual Basic Macro ("extract_trajectory_locs_from_HYSPLIT.vbs") was written by UT/CEER to process the output from the individual back-trajectory runs. The macro extracts the hourly trajectory positions from the standard HYSPLIT output ASCII text file and rounds the hourly latitude/longitude locations to an integer one degree latitude by one degree longitude grid. The hourly trajectory locations are exported to a comma-delimited ASCII text file. A LINUX-based program is used to concatenate all output data for each area. These data were imported into MicroSoft Access Database for further processing.

The ozone data summarized in Section 2.1 of this report were imported into Microsoft Access Database. A MicroSoft Visual Basic Macro ("hysplit_climatology1.vbs") was written by UT/CEER to process the ozone data for merging with the hourly back-trajectory positions. A data table was generated that reported the maximum ozone concentration averaged over 8 hours for the DFW and HGB areas for each day during the April through October period for the years 2001 through 2005. For each month, the highest ozone days were defined as the top 20 percent days ranked by the descending maximum ozone concentrations for each area. The lowest ozone days were defined as the lowest 20 percent days ranked by descending maximum ozone concentrations for each area. Based on the selected 20 percent days for each month for each area, the UT/CEER macro generated the necessary MicroSoft Access queries to extract the hourly trajectory locations for the appropriate ozone days. For each scenario (e.g., top 20 percent ozone days during June for DFW), the residence time within each one degree latitude by one degree longitude grid cell was calculated by summing the number of back-trajectory hours with locations that occurred within that one degree grid cell. This summation was repeated for all one degree grid cells within a geographic area larger than the continental US. The percentage of residence time was calculated by dividing the total number of hours within each one degree grid cell by the total number of hours across all grid cells. The percent residence time by grid cell data were then exported from the database as individual comma-delimited ASCII text files for each scenario.

The methodology summarized in the previous paragraph was repeated using a second MicroSoft Visual Basic Macro ("hysplit_climatology1_75ppb.vbs") to extract all days for each area that were characterized by a maximum ozone concentration averaged over 8 hours of 75 ppb or greater and 85 ppb or greater regardless of the month or year of occurrence. The percentages of residence time by grid cell were also exported from the database as individual comma-delimited ASCII text files for each area.

3.4 Contouring the residence time output

A third MicroSoft Visual Basic Macro ("hysplit_climatology2.vbs") was written by UT/CEER to automate the generation of the percent residence time contour maps for each of the selected scenarios (e.g., top 20 percent ozone days for June for DFW). The contour maps were generated using Golden Software's Surfer (www.goldensoftware.com). The Kriging scheme was used to interpolate the residence time percentages to a one degree latitude by one degree longitude grid. The gridded data were contoured using a 0.2 percent contour interval.

Figure 2-1 presents an example of the final residence time map for the HGA ozone nonattainment area for all days with maximum ozone concentrations averaged over 8 hours of 85 ppb or greater. For comparison, Figure 2-2 presents the individual five-day back-trajectories for the 198 days used to develop the contoured residence map shown in Figure 2-1. The individual back-trajectories displayed in Figure 2-2 clearly provide a qualitative summary of the long-range flow patterns and upwind geographic areas prior to high ozone days in HGB. However, the overlap of the individual back-trajectories masks the relatively frequency of occurrence of the hourly back-trajectory positions over upwind geographic areas that is captured quantitatively by the contoured residence time map shown in Figure 2-1.

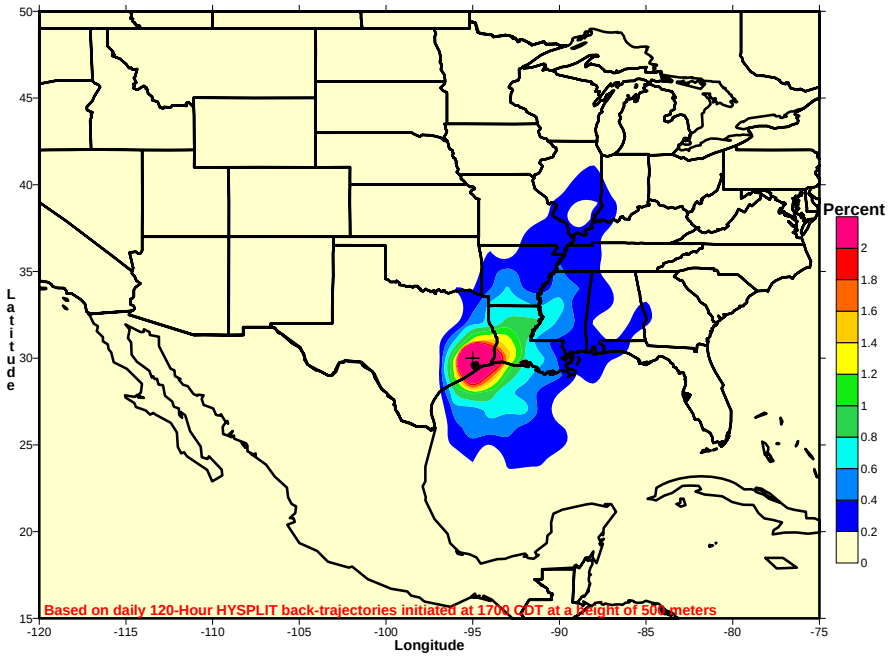


Figure 3-1. Five-day back-trajectory residence time in percent for all days with a daily maximum ozone concentration greater than or equal to 85 ppb for the years 2001 through 2005 for Houston/Galveston/Brazoria.

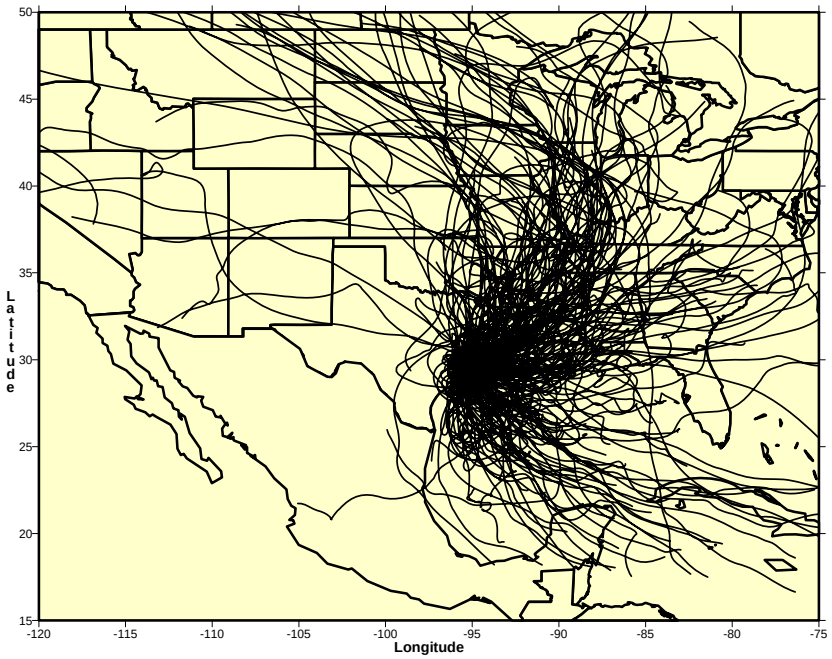


Figure 3-2. Five-day back-trajectories (198 total) for all days with a daily maximum ozone concentration greater than or equal to 85 ppb for the years 2001 through 2005 for Houston/Galveston/Brazoria.

3.5 Discussion of uncertainties

There are multiple sources of uncertainties associated with the generation of back-trajectories using the HYSPLIT application. These uncertainties primarily arise from the generation of the three-dimensionally gridded meteorological dataset. Sources of uncertainty include, but are not limited to, errors associated with the available meteorological observational data, performance of the NCEP meteorological forecast models during the integration period, and errors introduced by the data assimilation technique used to construct the dataset. In addition, the relatively low horizontal spatial resolution and temporal resolution (3 hours for the EDAS datasets) probably captures the prevailing synoptic flow during weather patterns dominated by large-scale and slow-moving systems that are well-simulated by the meteorological models. The EDAS archive may not properly capture the impacts of localized or mesoscale weather features, such as the land-sea breeze along coastal Texas, whether or not these features are well-simulated by the meteorological models. Additional uncertainty is introduced by errors in the simulation of large-scale vertical motion by the meteorological models in combination with the vertical resolution of the archived datasets (approximately 250 meters in the lower atmosphere for the EDAS datasets). In addition, the calculation of the back-trajectories can be sensitive to the starting height above ground depending on the change of wind direction and wind speed with respect to height above the surface over the geographic areas of interest.

Further discussion of the sources of uncertainty associated with the calculation of trajectories using the HYSPLIT model can be found at the HYSPLIT website (http://www.arl.noaa.gov/ready/hysplit4.html). In general, the user is advised that the HYSPLIT back-trajectories used to construct the residence time maps presented in this report should not be interpreted as precise tracks of air parcels; however, patterns that emerge when analyzing a relatively large number of trajectories (such as those patterns presented in the residence time maps summarized in this report) should provide a good indication of potential long-range transport due to the prevailing large-scale flow regime.

4.0 Results

The primary goal of this project was to generate residence time contour maps that visually summarize the most frequent geographic areas upwind of the DFW and HGB ozone nonattainment areas prior to low and high ozone days grouped by month. Each residence time map displays the frequency of occurrence of HYSPLIT back-trajectory hourly end points over a US geographic map.

Appendices A and B provide the residence time contour map results for the DFW and HGB nonattainment areas, respectively. The first map in each appendix presents the percent residence time for all ozone days with a maximum ozone concentration averaged over 8 hours of 75 ppb or greater during the years 2001 through 2005. The second map presents the percent residence time for all ozone days with a maximum ozone concentration averaged over 8 hours of 85 ppb or greater during the years 2001 through 2005. The next maps in each appendix present the results for the 75 ppb and 85 ppb high ozone days for the months of June, August, and September only. The remaining fourteen maps in each appendix provide the residence time analyses for the top 20% ozone days and lowest 20% ozone days for each month during the April through October period. All available data for the years 2001 through 2005 were used to generate the residence time maps for each month. High and low ozone days were determined based on the maximum ozone concentrations averaged over 8 hours at the monitoring stations shown in Table 2-1 and Table 2-2.

5.0 Recommendations

The results presented in this report were based on back-trajectories initiated at starting heights of 500 meters above the surface. The measurement network installed in support of the Texas Air Quality Study 2 (TexAQS II) included an enhancement to the radar wind profiler network to operate a number of additional profiler stations in rural areas located throughout eastern Texas. Early analysis of the mixing heights based on measurements collected at the TexAQS II radar wind profiler stations indicates that analyzed mixing heights during the late afternoon hours on summer days are often 1-1.5 km along coast increasing to 2-2.5 km inland. As mentioned in Section 2.0 of this report, the calculation of back-trajectories can be quite sensitive to the starting height above ground depending on the change of wind direction and wind speed with respect to height over the geographic areas of interest. The 500-meter starting height used in this report should be well within the mixed layer on most summer days. However, the TexAQS II observations of mixing heights suggest that residence time maps generated using back-trajectories initiated at starting heights of 1000 meters or even 1500 meters would be useful to determine the robustness of the spatial transport patterns presented in this report.

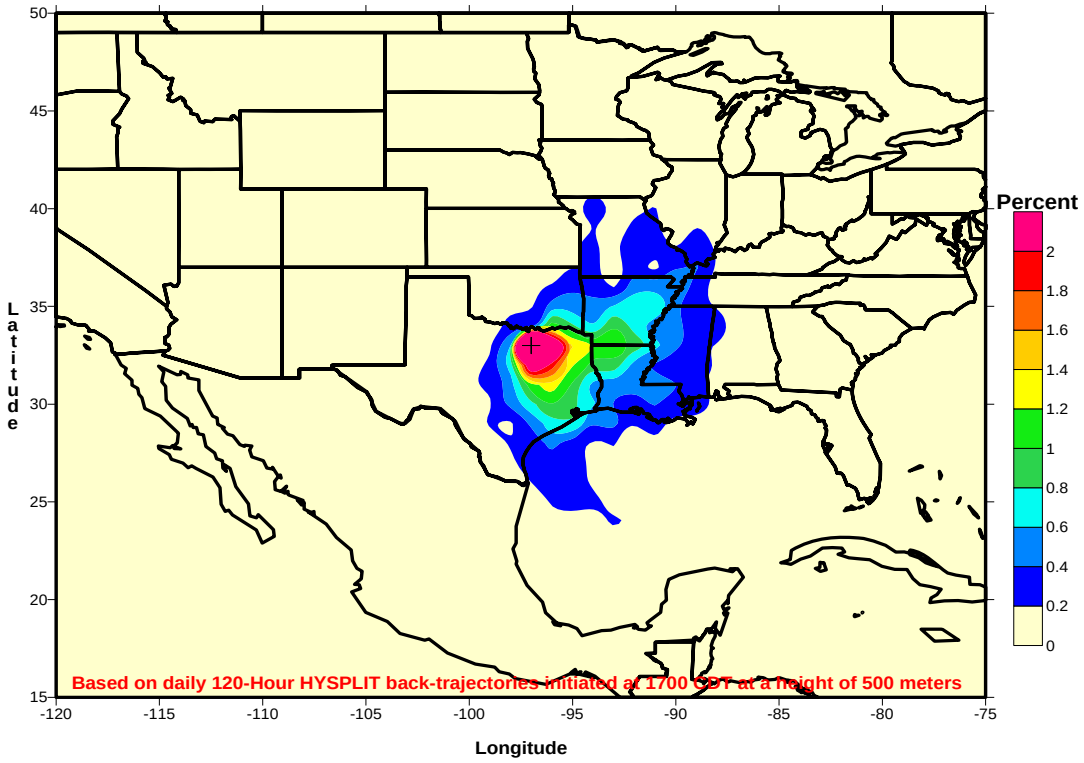
6.0 References

The University of Texas at Austin, 2006. *Monthly Back-Trajectory Analyses on High and Low Ozone Days for the Texas Near Nonattainment Areas for the Years 2001 through 2005*. Prepared for The City of Victoria and The Texas Commission on Environmental Quality. October 2006.

Appendix A. Five-Day Back-Trajectory Residence Time Maps for Dallas/Fort Worth.

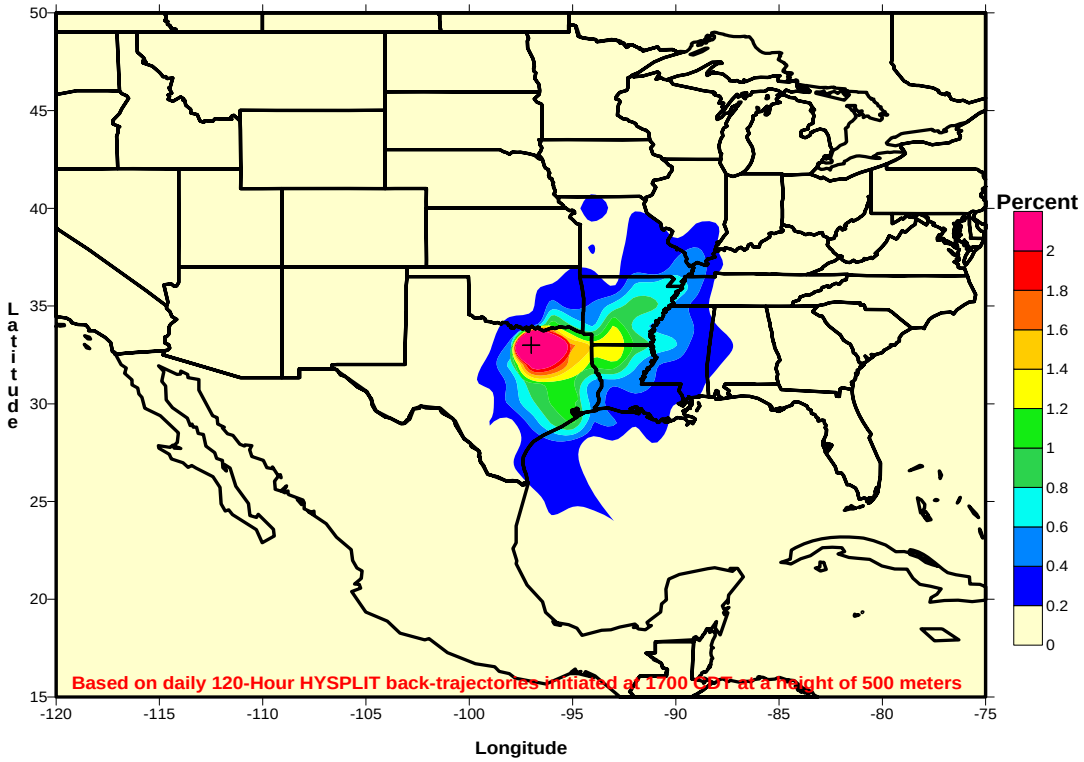
Trajectory Residence Time in Percent for Days with 8-Hour Ozone >= 75 ppb

Years 2001 - 2005: DALLAS/FORT WORTH



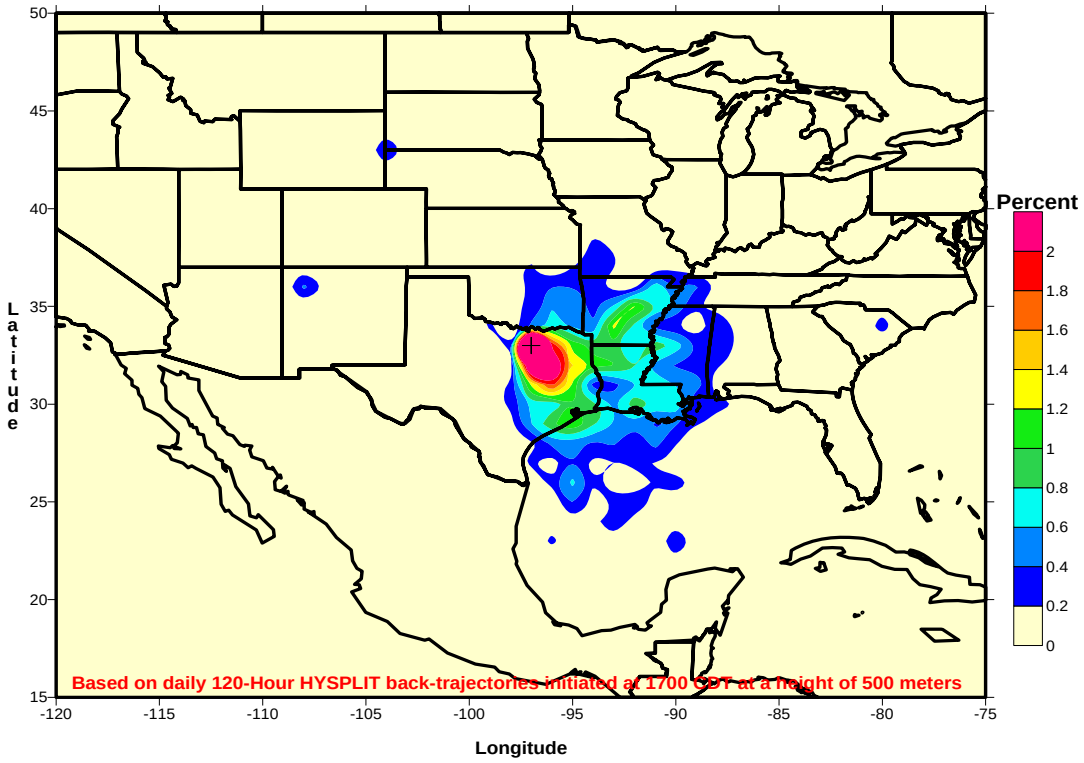
Trajectory Residence Time in Percent for Days with 8-Hour Ozone >= 85 ppb

Years 2001 - 2005: DALLAS/FORT WORTH



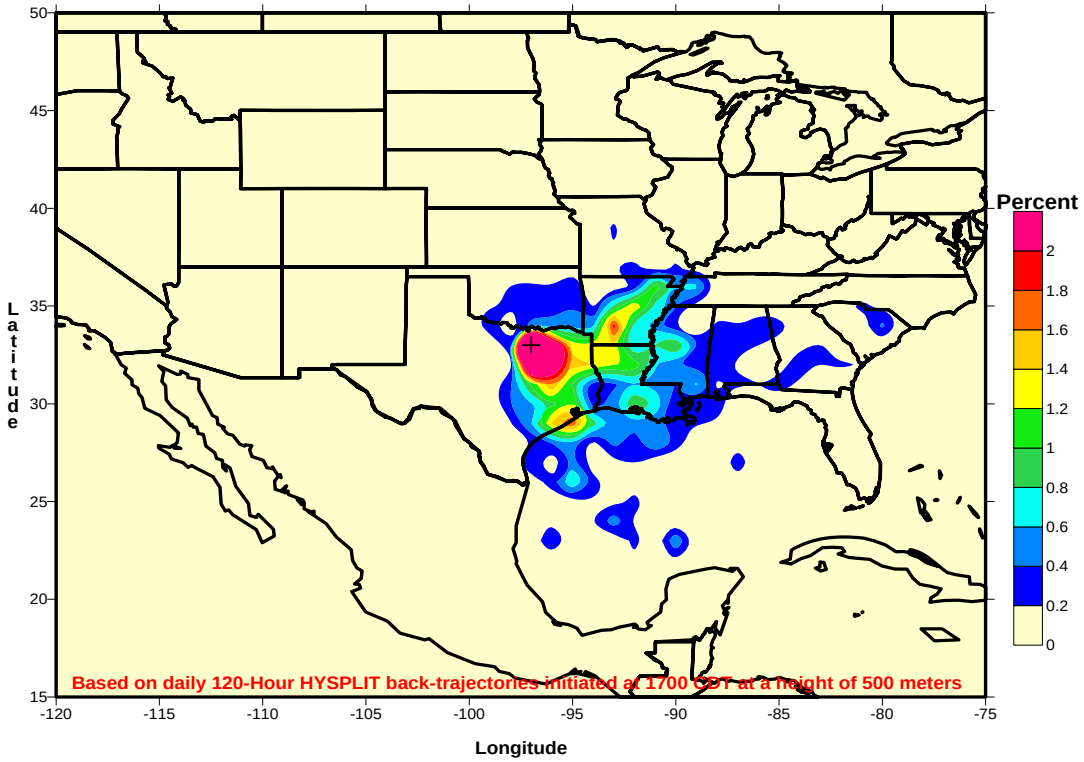
Trajectory Residence Time in Percent for Days with 8-Hour Ozone >= 75 ppb

Years 2001 - 2005: June; DALLAS/FORT WORTH



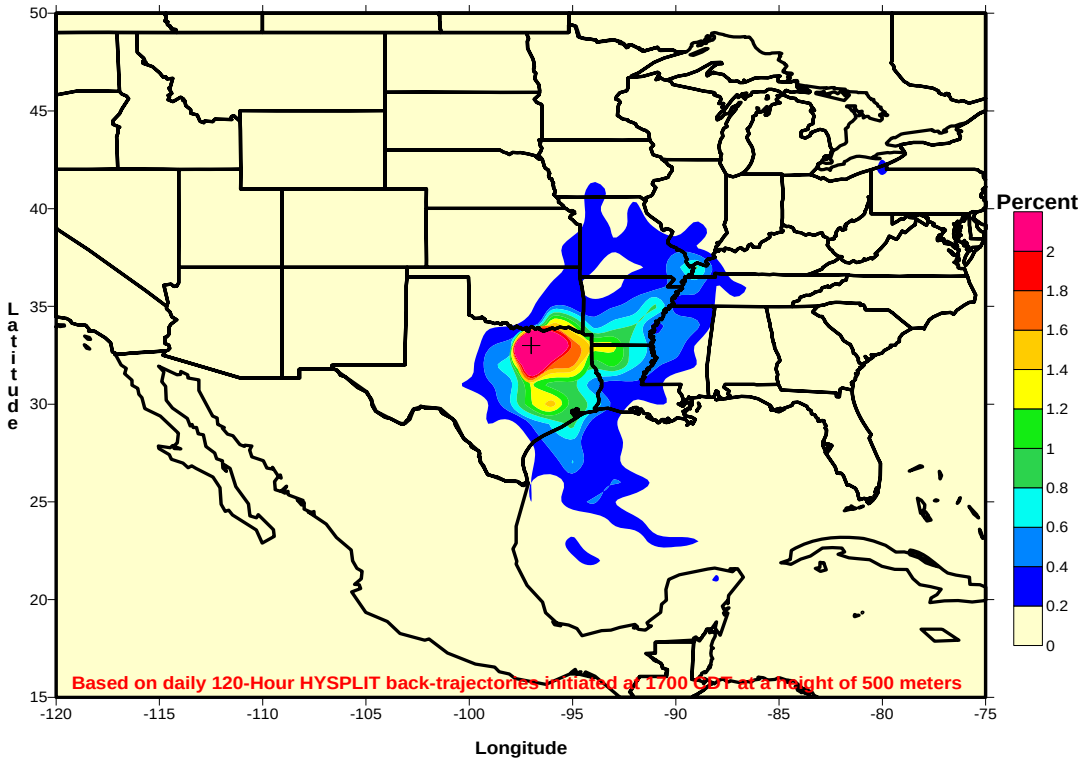
Trajectory Residence Time in Percent for Days with 8-Hour Ozone >= 85 ppb

Years 2001 - 2005: June; DALLAS/FORT WORTH



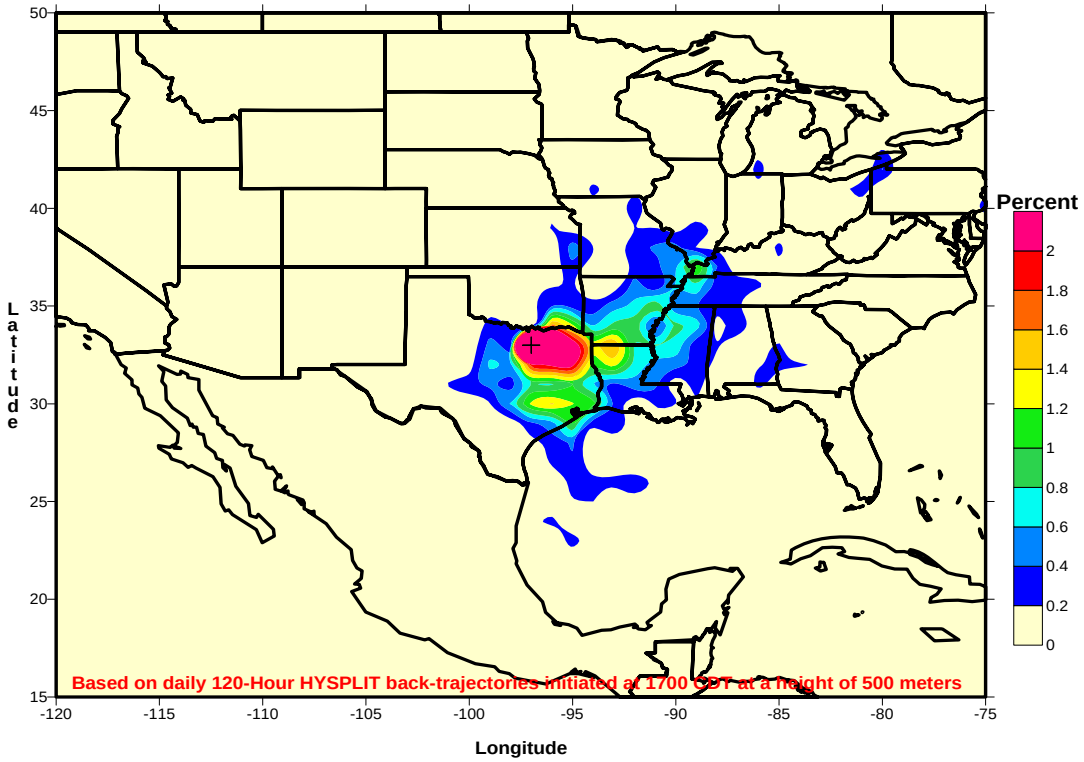
Trajectory Residence Time in Percent for Days with 8-Hour Ozone >= 75 ppb

Years 2001 - 2005: August; DALLAS/FORT WORTH



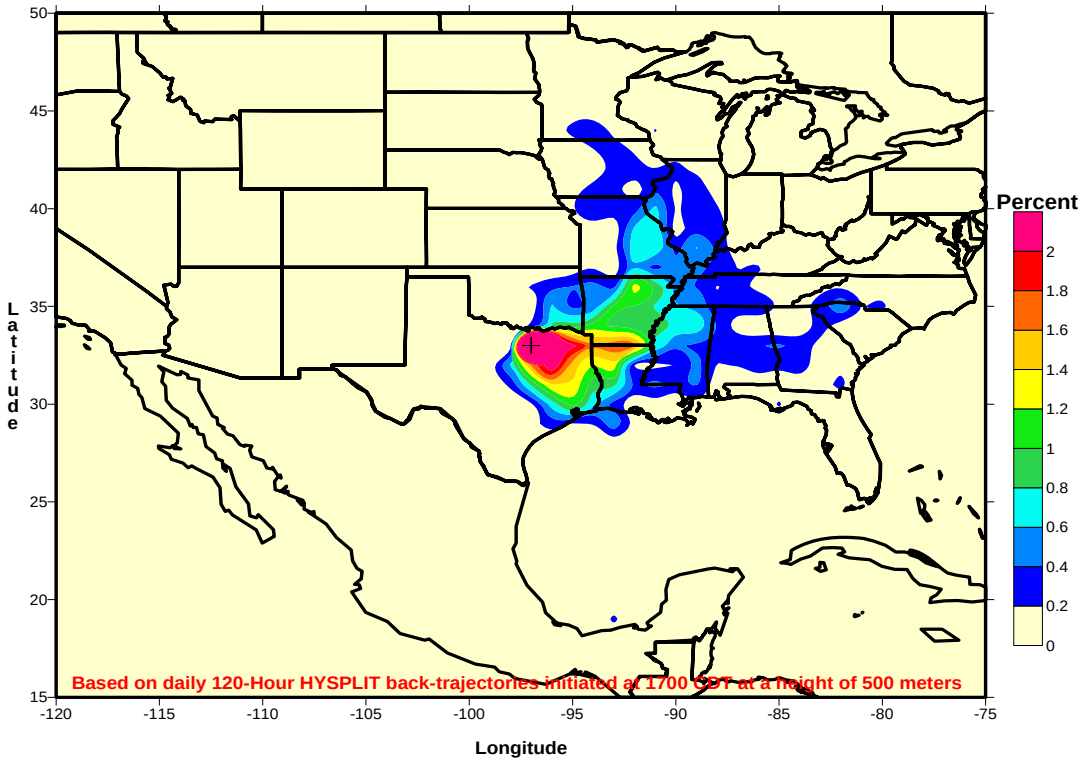
Trajectory Residence Time in Percent for Days with 8-Hour Ozone >= 85 ppb

Years 2001 - 2005: August; DALLAS/FORT WORTH



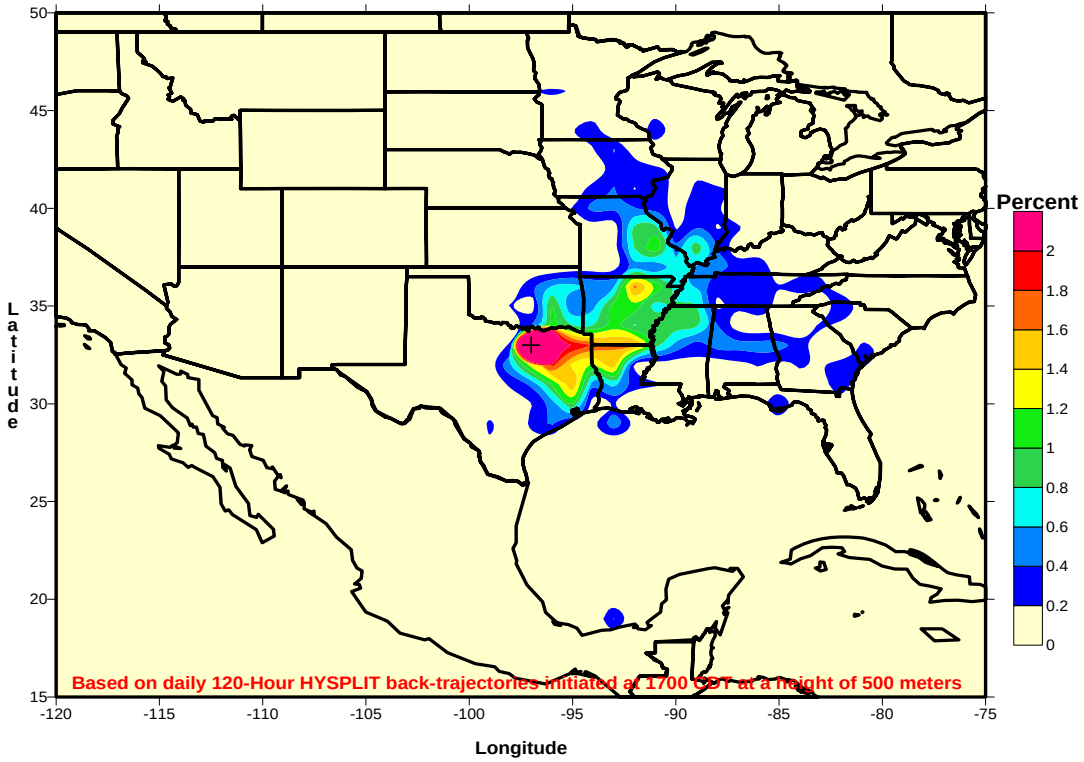
Trajectory Residence Time in Percent for Days with 8-Hour Ozone >= 75 ppb

Years 2001 - 2005: September; DALLAS/FORT WORTH



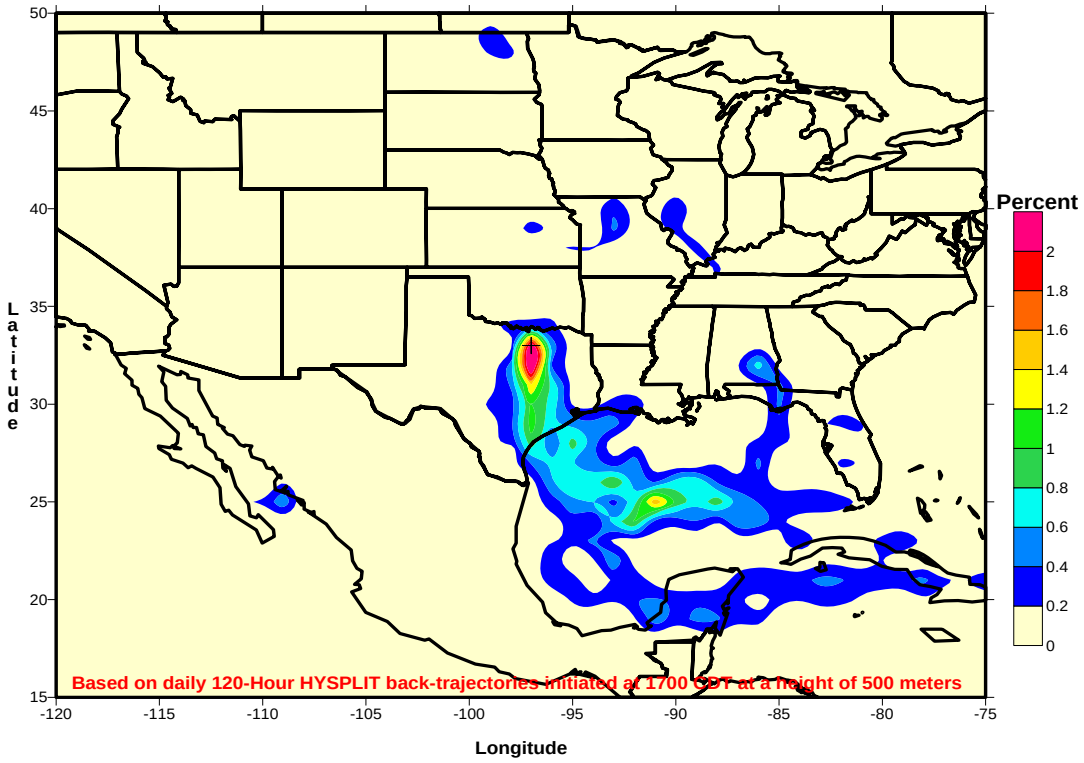
Trajectory Residence Time in Percent for Days with 8-Hour Ozone >= 85 ppb

Years 2001 - 2005: September; DALLAS/FORT WORTH



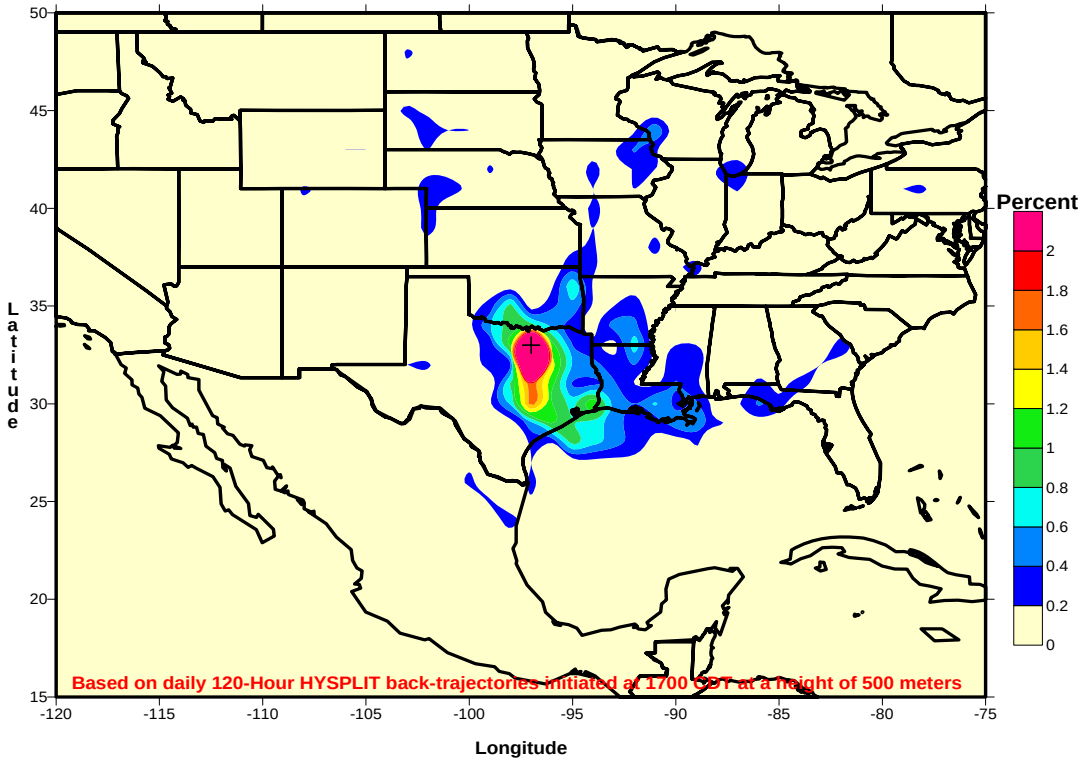
Trajectory Residence Time in Percent for the Lowest 20% 8-Hour Ozone Days

Years 2001 - 2005: April; DALLAS/FORT WORTH



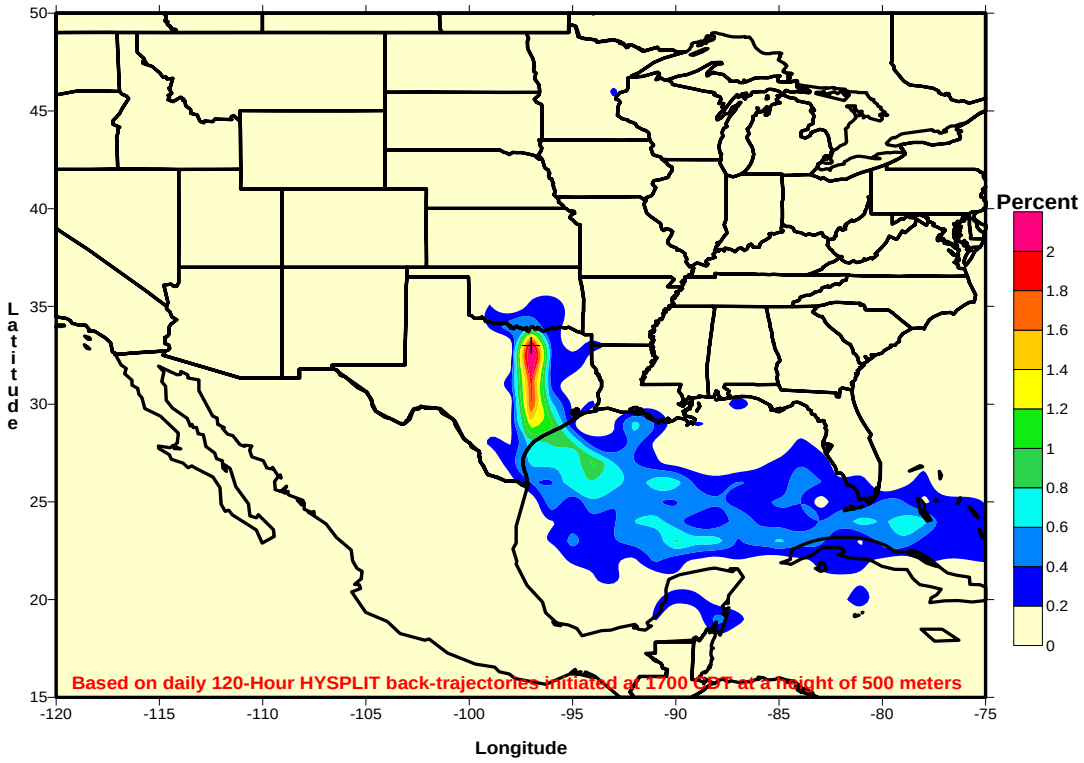
Trajectory Residence Time in Percent for the Top 20% 8-Hour Ozone Days

Years 2001 - 2005: April; DALLAS/FORT WORTH



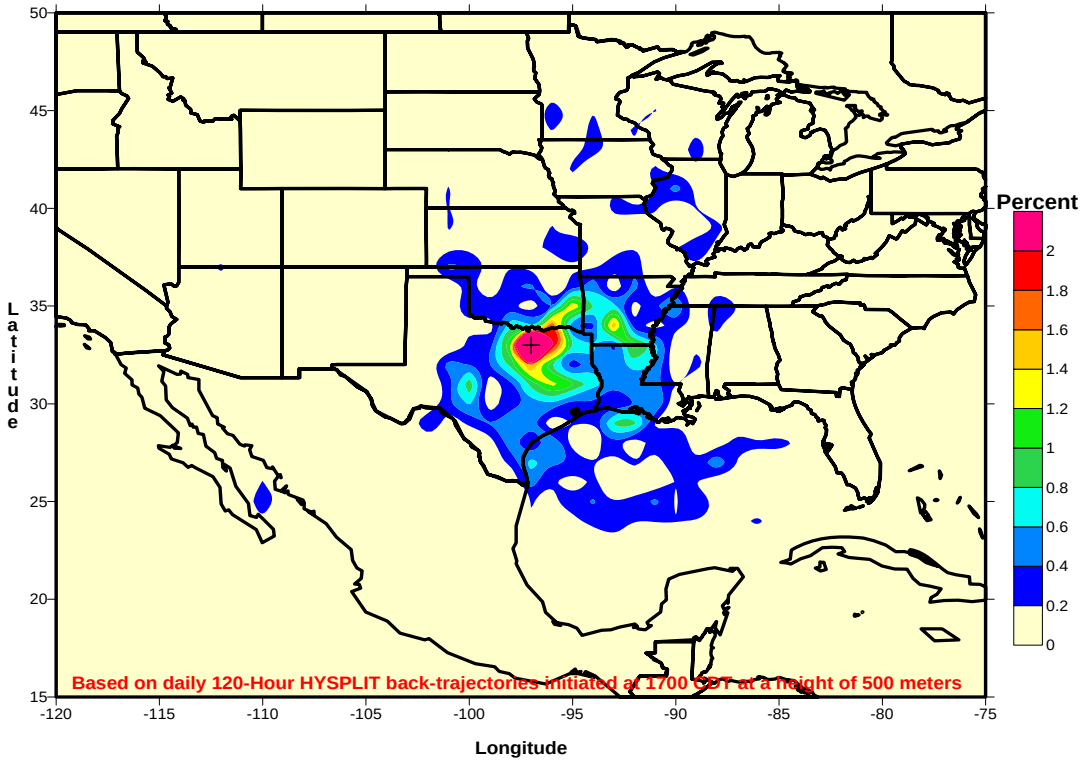
Trajectory Residence Time in Percent for the Lowest 20% 8-Hour Ozone Days

Years 2001 - 2005: May; DALLAS/FORT WORTH



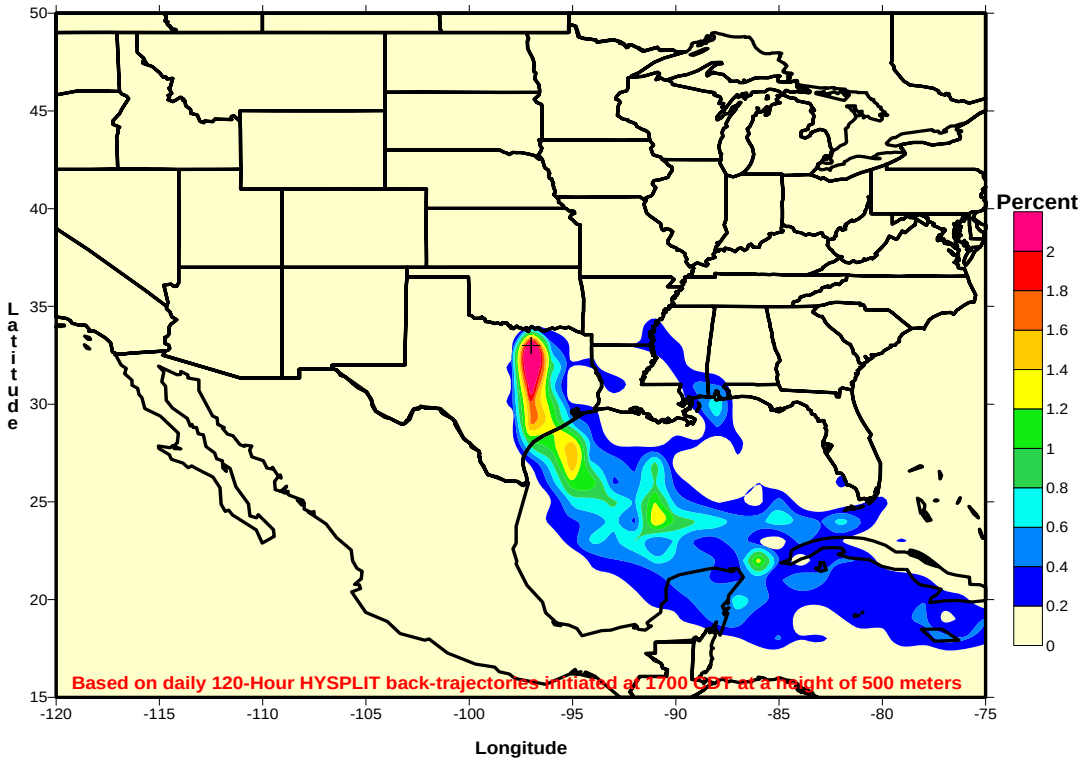
Trajectory Residence Time in Percent for the Top 20% 8-Hour Ozone Days

Years 2001 - 2005: May; DALLAS/FORT WORTH



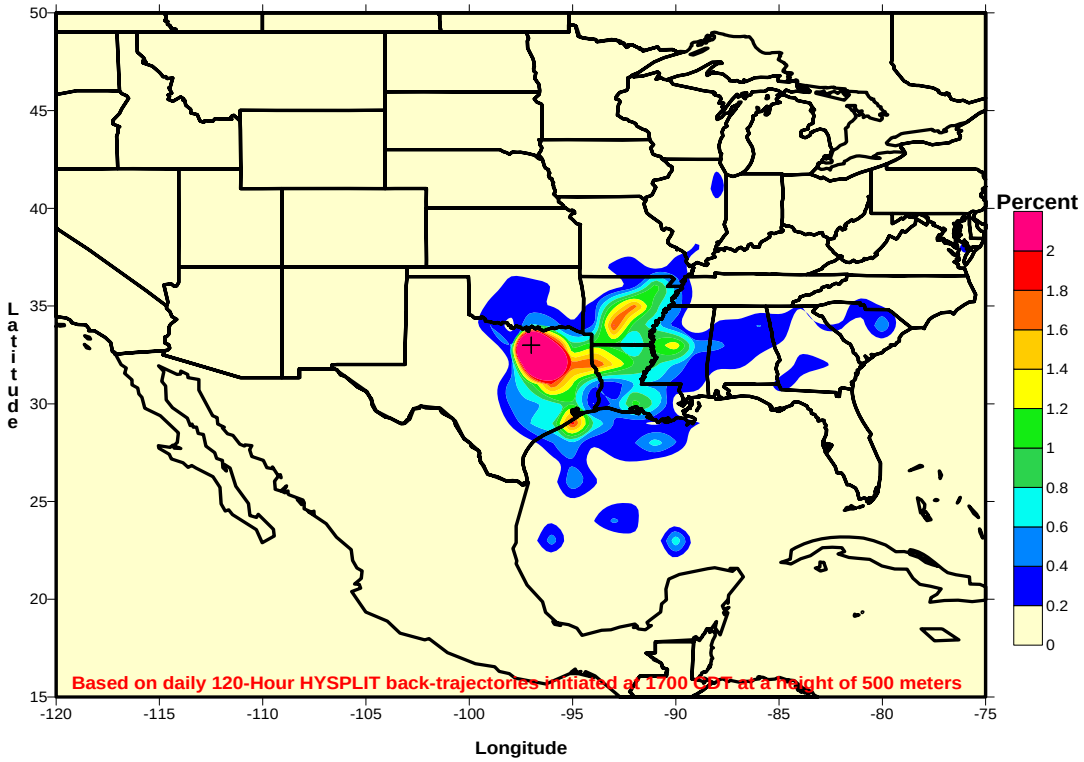
Trajectory Residence Time in Percent for the Lowest 20% 8-Hour Ozone Days

Years 2001 - 2005: June; DALLAS/FORT WORTH



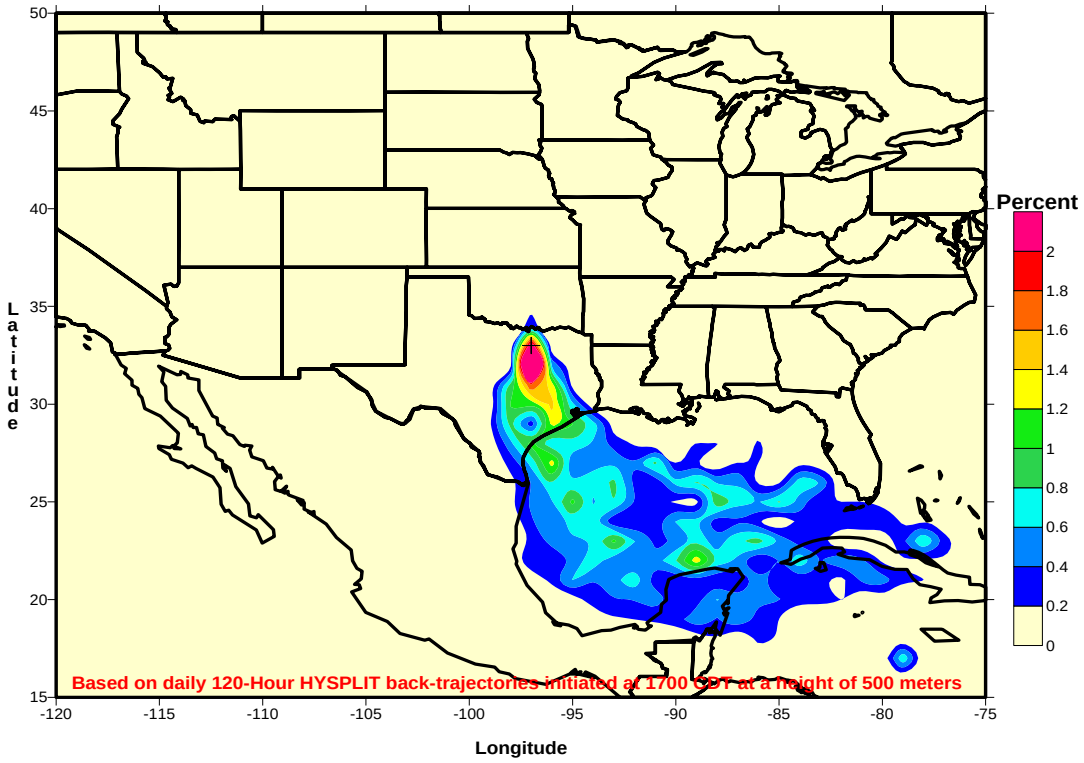
Trajectory Residence Time in Percent for the Top 20% 8-Hour Ozone Days

Years 2001 - 2005: June; DALLAS/FORT WORTH



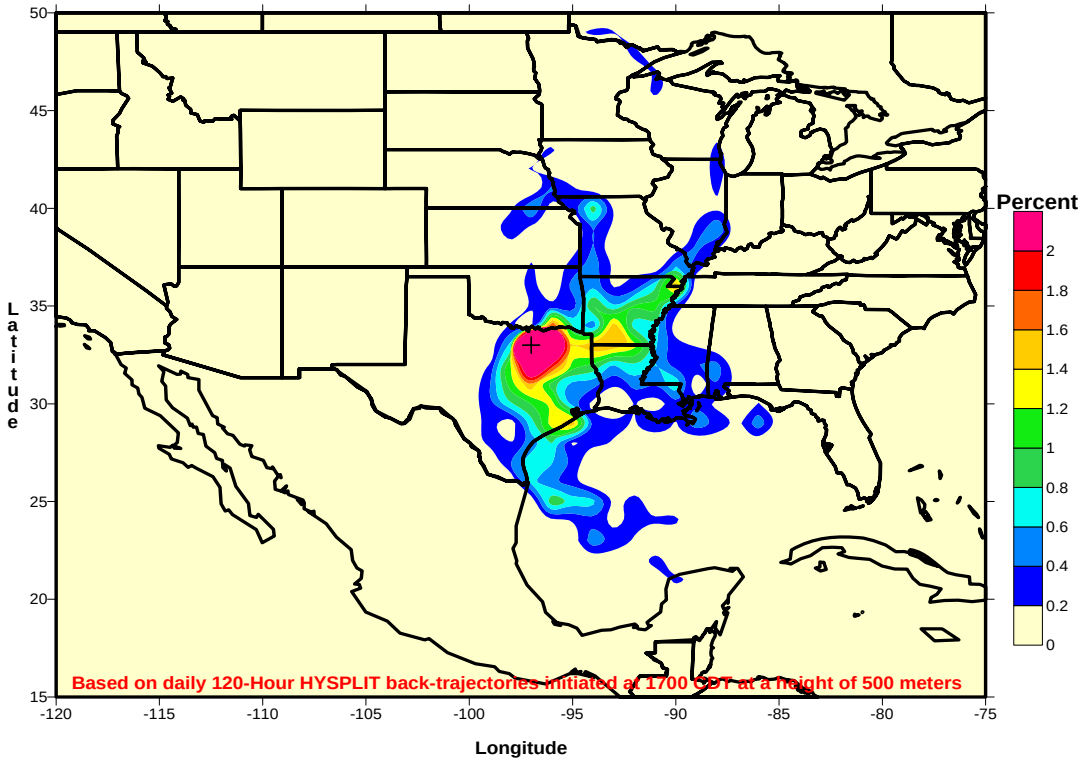
Trajectory Residence Time in Percent for the Lowest 20% 8-Hour Ozone Days

Years 2001 - 2005: July; DALLAS/FORT WORTH



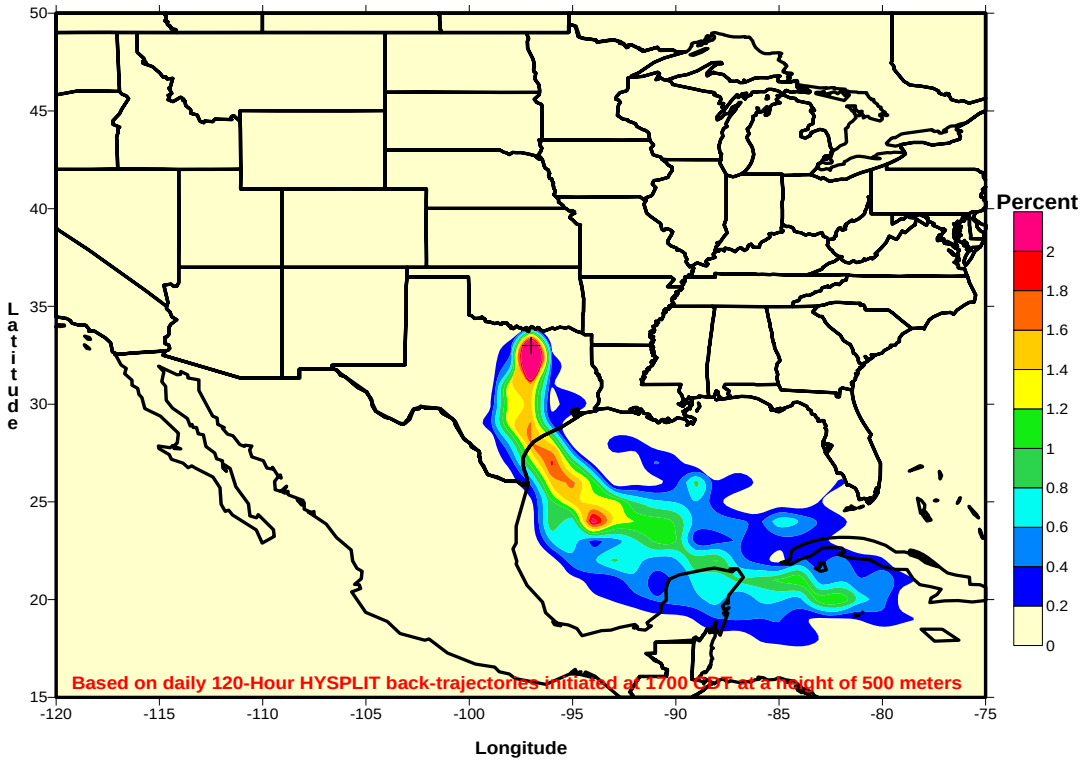
Trajectory Residence Time in Percent for the Top 20% 8-Hour Ozone Days

Years 2001 - 2005: July; DALLAS/FORT WORTH



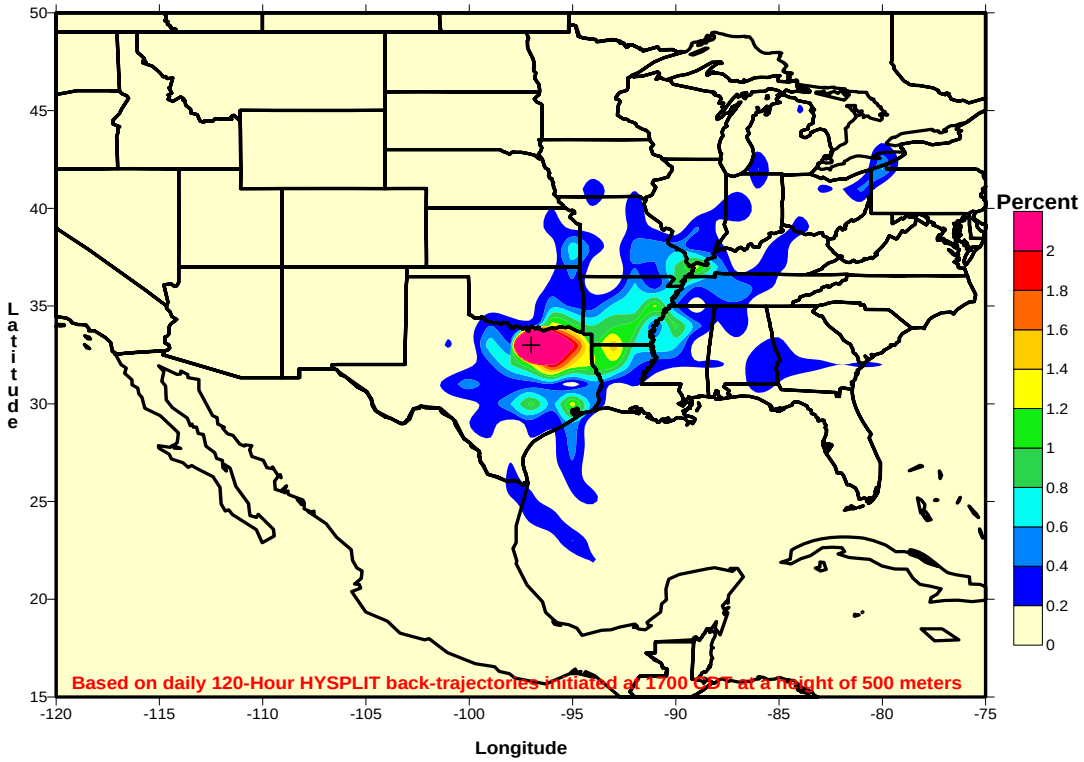
Trajectory Residence Time in Percent for the Lowest 20% 8-Hour Ozone Days

Years 2001 - 2005: August; DALLAS/FORT WORTH



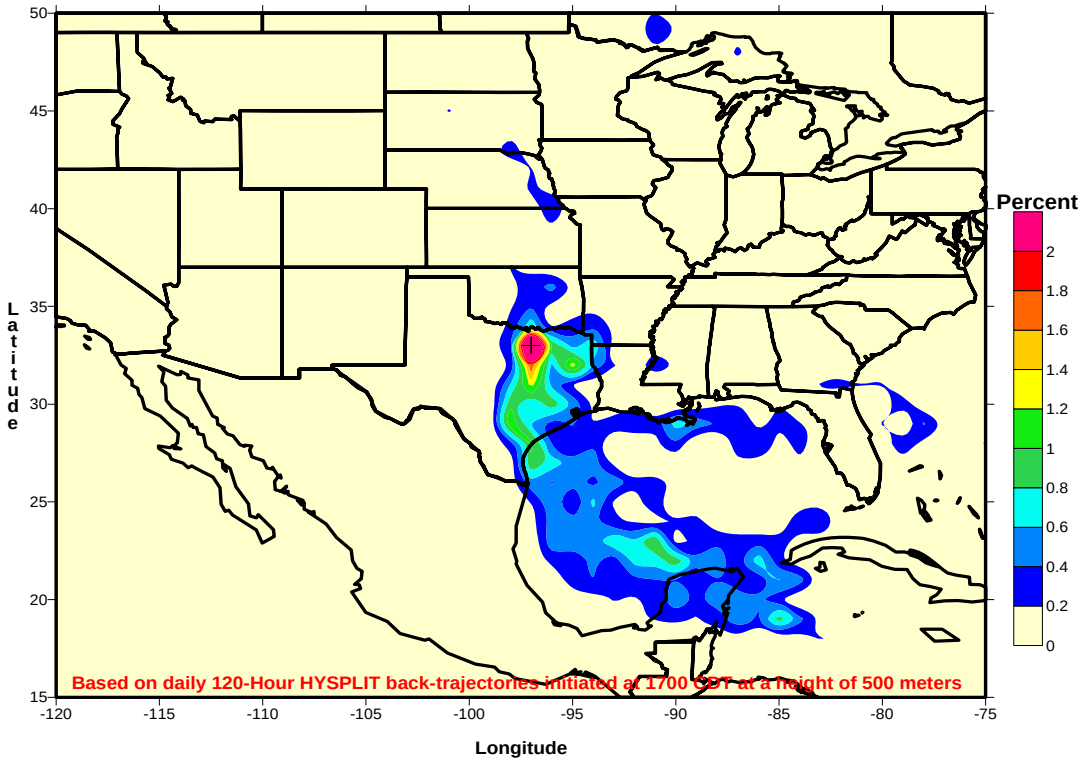
Trajectory Residence Time in Percent for the Top 20% 8-Hour Ozone Days

Years 2001 - 2005: August; DALLAS/FORT WORTH



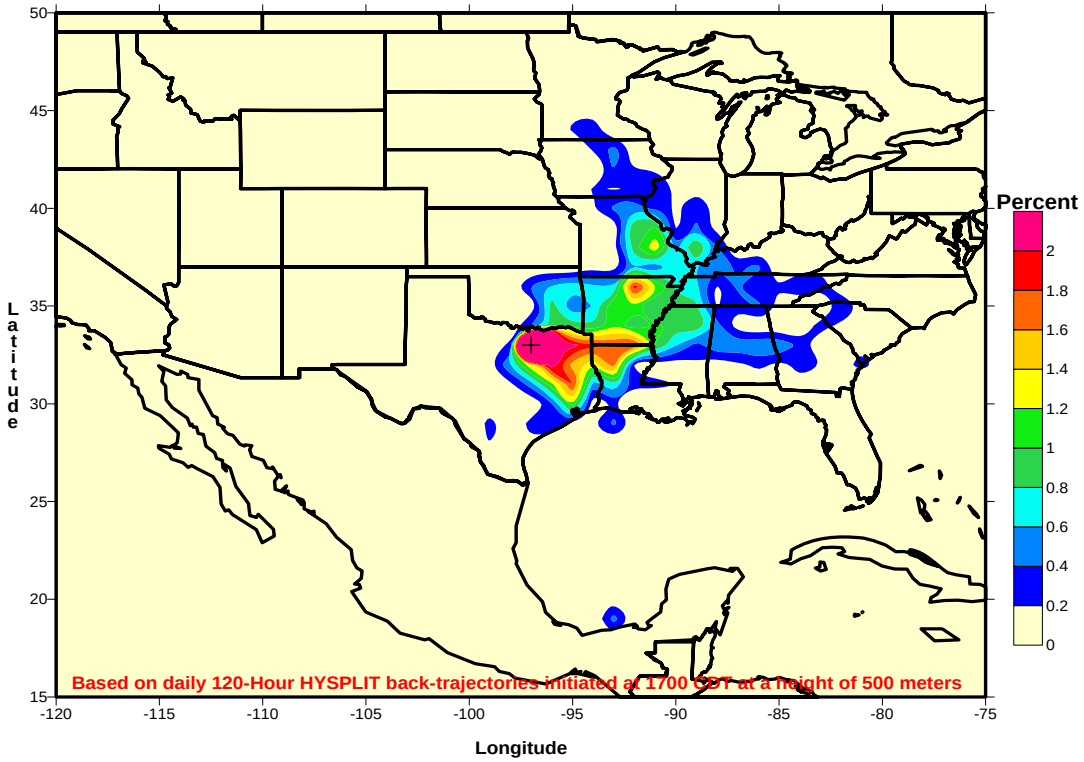
Trajectory Residence Time in Percent for the Lowest 20% 8-Hour Ozone Days

Years 2001 - 2005: September; DALLAS/FORT WORTH



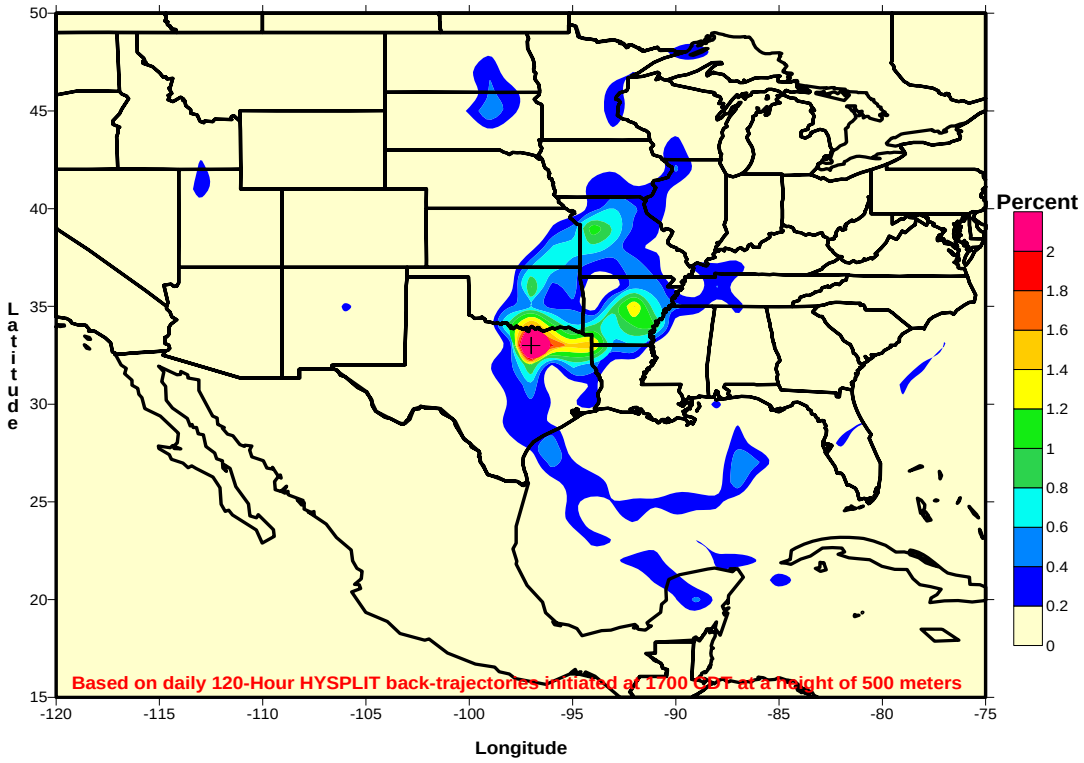
Trajectory Residence Time in Percent for the Top 20% 8-Hour Ozone Days

Years 2001 - 2005: September; DALLAS/FORT WORTH



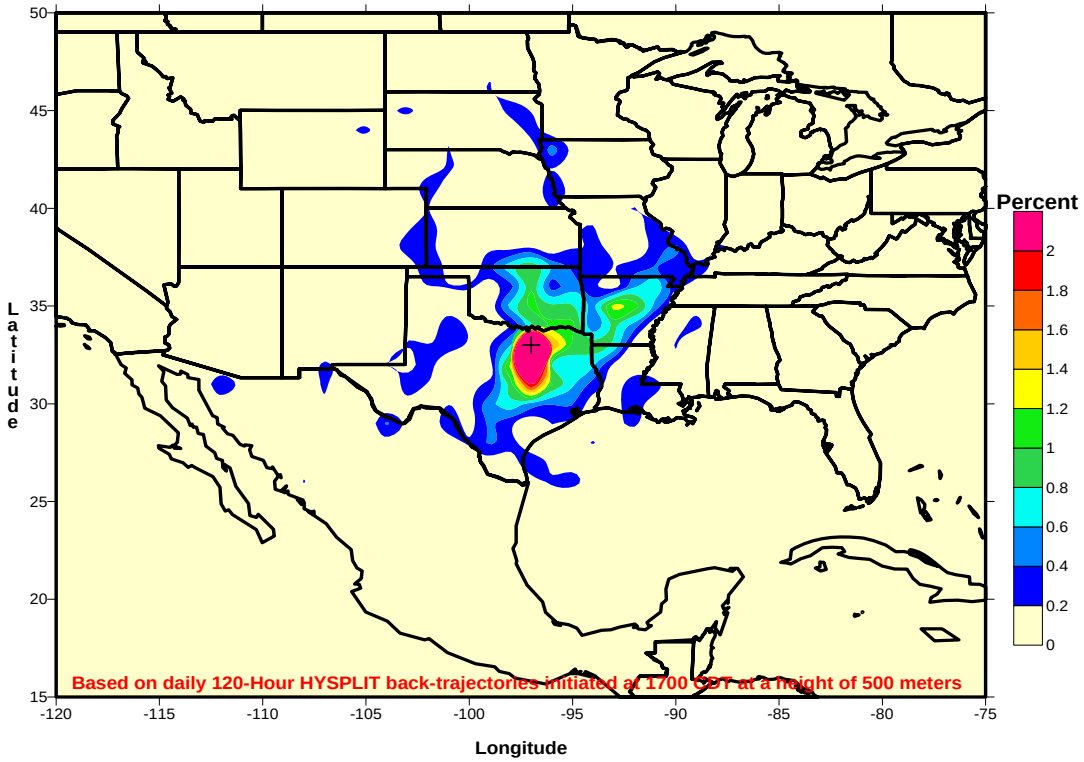
Trajectory Residence Time in Percent for the Lowest 20% 8-Hour Ozone Days

Years 2001 - 2005: October; DALLAS/FORT WORTH



Trajectory Residence Time in Percent for the Top 20% 8-Hour Ozone Days

Years 2001 - 2005: October; DALLAS/FORT WORTH

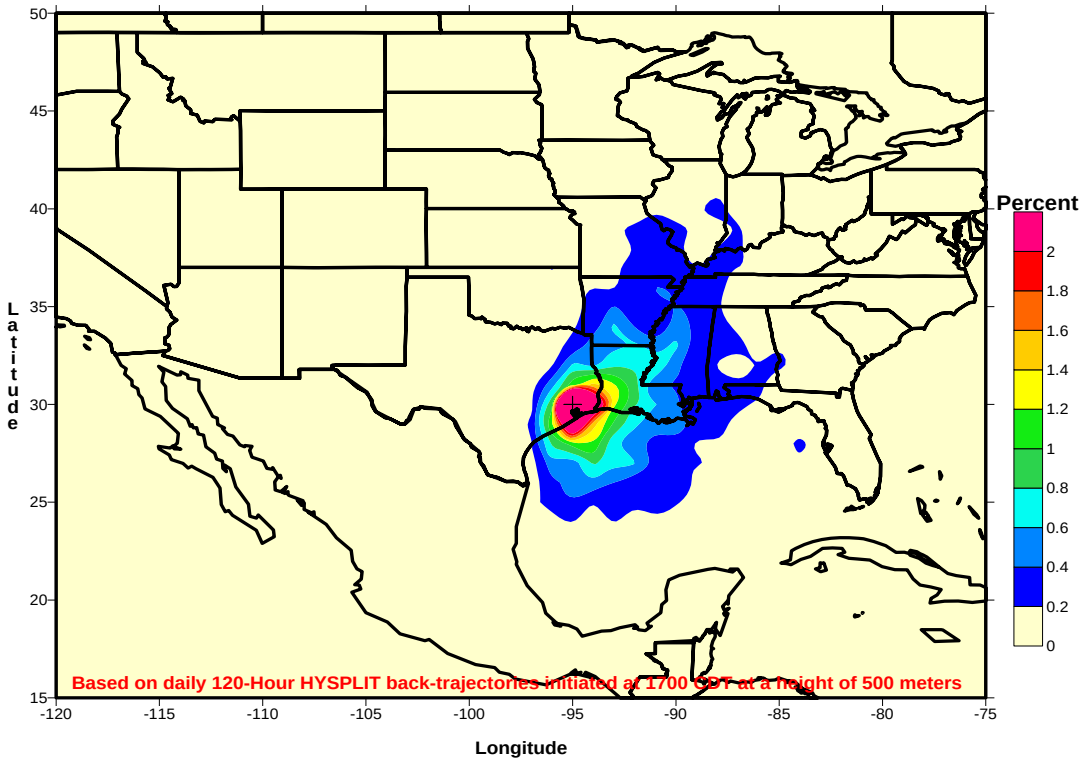


The University of Texas at Austin
October 19, 2006

Appendix B. Five-Day Back-Trajectory Residence Time Maps for Houston/Galveston/Brazoria.

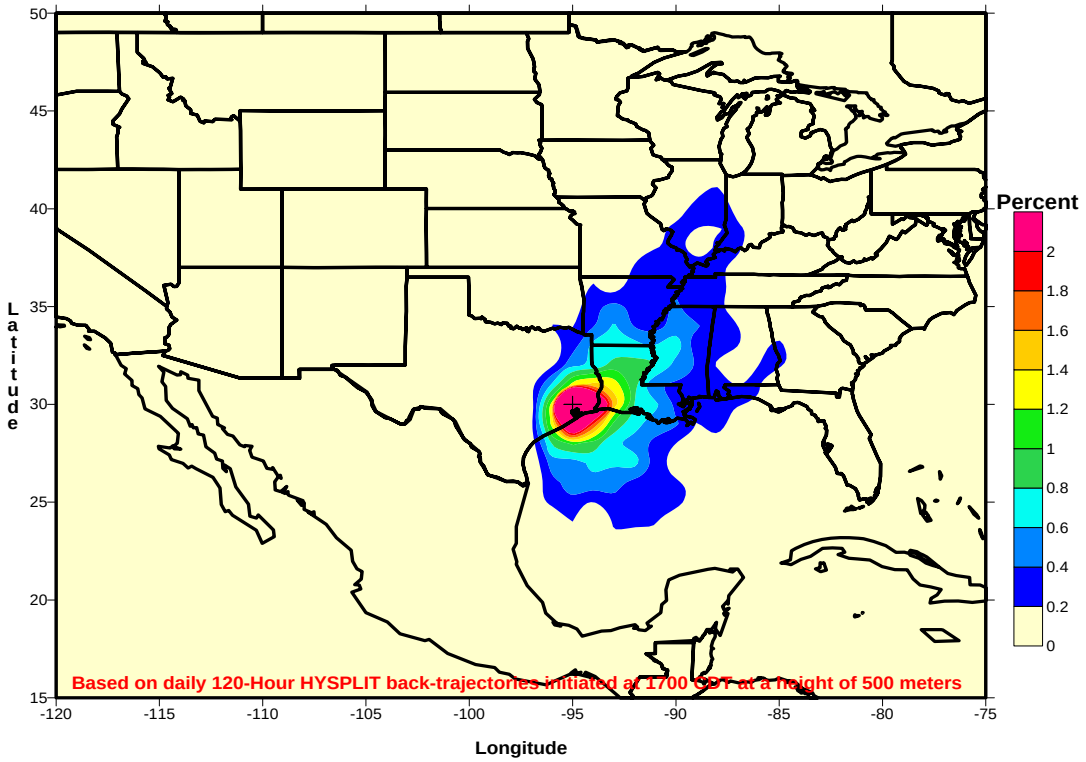
Trajectory Residence Time in Percent for Days with 8-Hour Ozone >= 75 ppb

Years 2001 - 2005: HOUSTON/GALVESTON/BRAZORIA



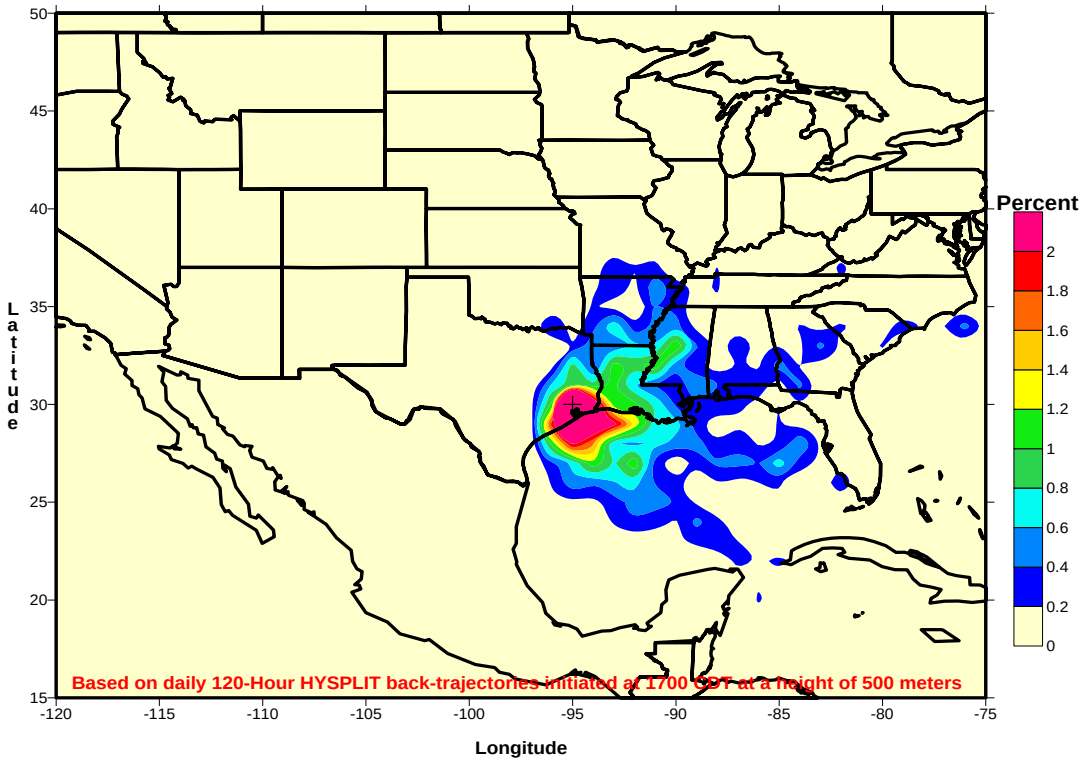
Trajectory Residence Time in Percent for Days with 8-Hour Ozone >= 85 ppb

Years 2001 - 2005: HOUSTON/GALVESTON/BRAZORIA



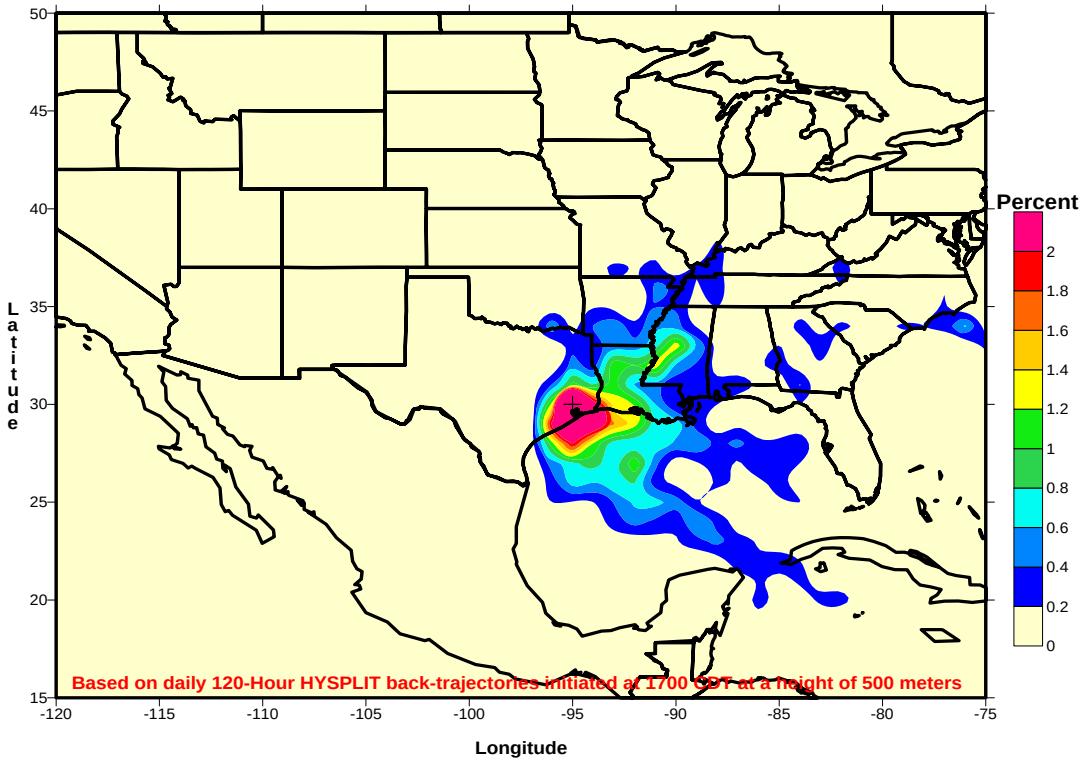
Trajectory Residence Time in Percent for Days with 8-Hour Ozone >= 75 ppb

Years 2001 - 2005: June; HOUSTON/GALVESTON/BRAZORIA



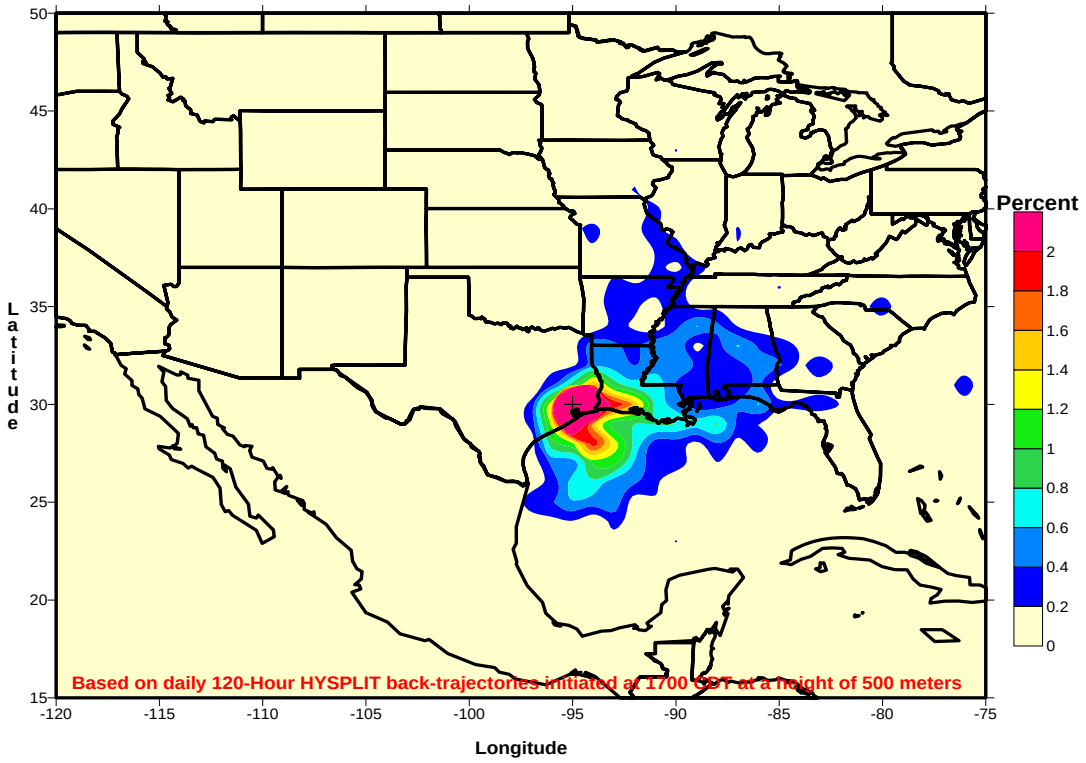
Trajectory Residence Time in Percent for Days with 8-Hour Ozone >= 85 ppb

Years 2001 - 2005: June; HOUSTON/GALVESTON/BRAZORIA



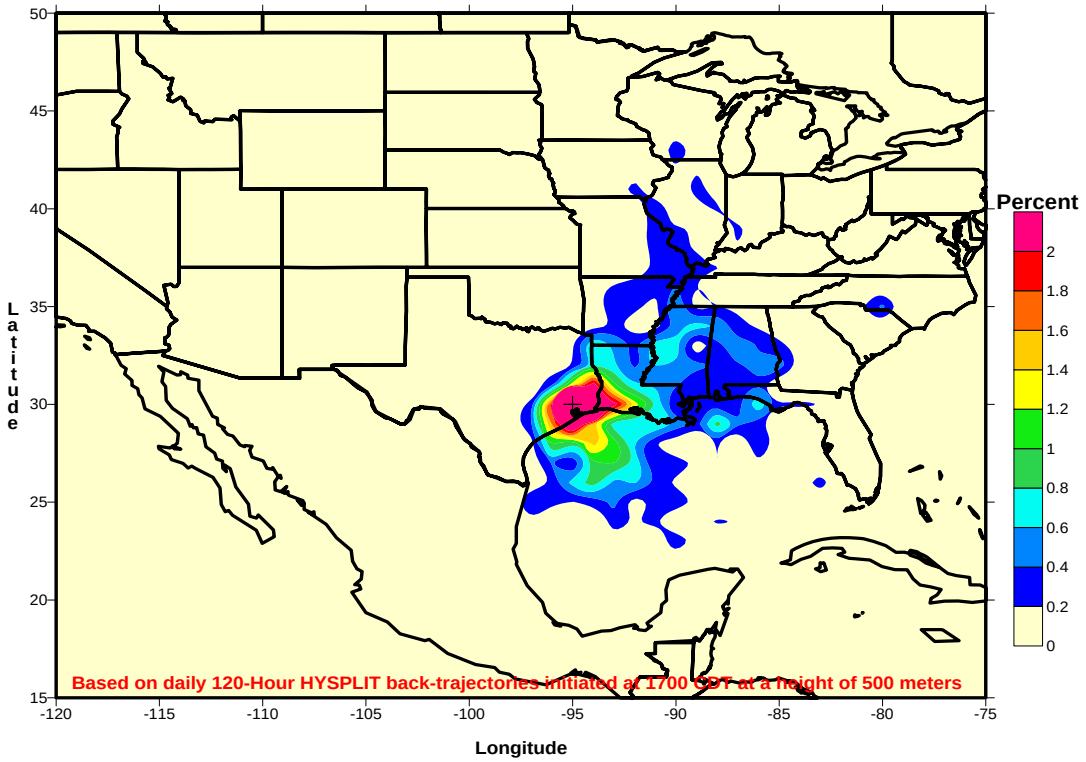
Trajectory Residence Time in Percent for Days with 8-Hour Ozone >= 75 ppb

Years 2001 - 2005: August; HOUSTON/GALVESTON/BRAZORIA



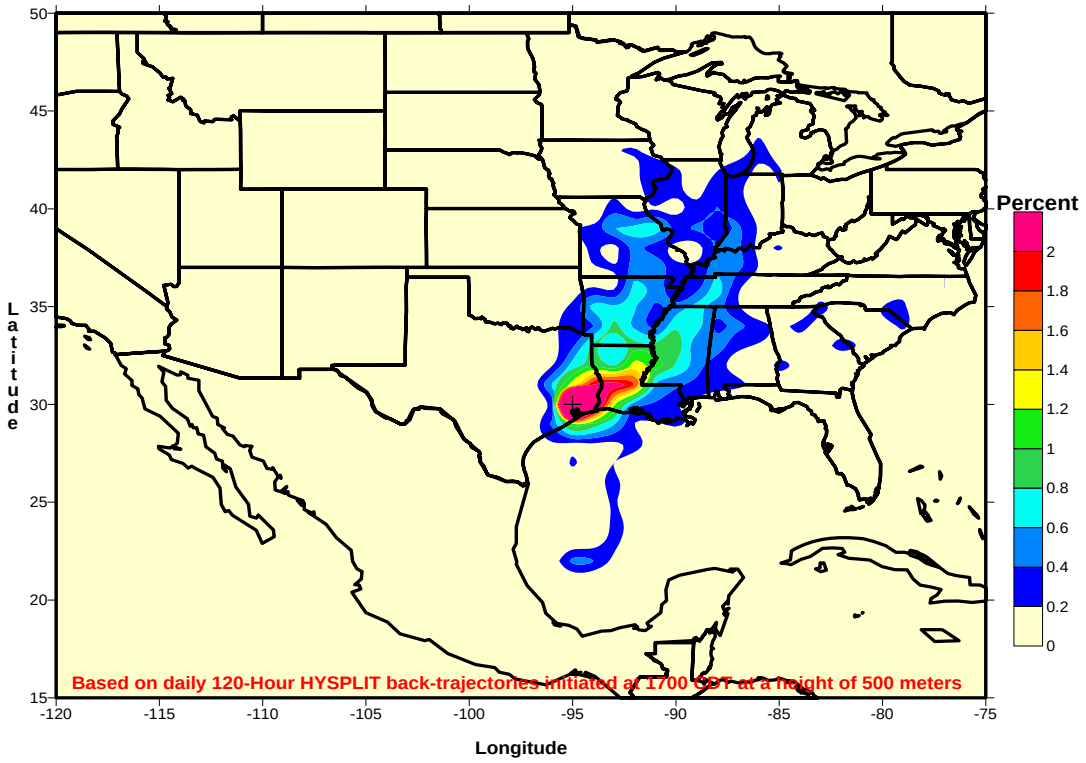
Trajectory Residence Time in Percent for Days with 8-Hour Ozone >= 85 ppb

Years 2001 - 2005: August; HOUSTON/GALVESTON/BRAZORIA



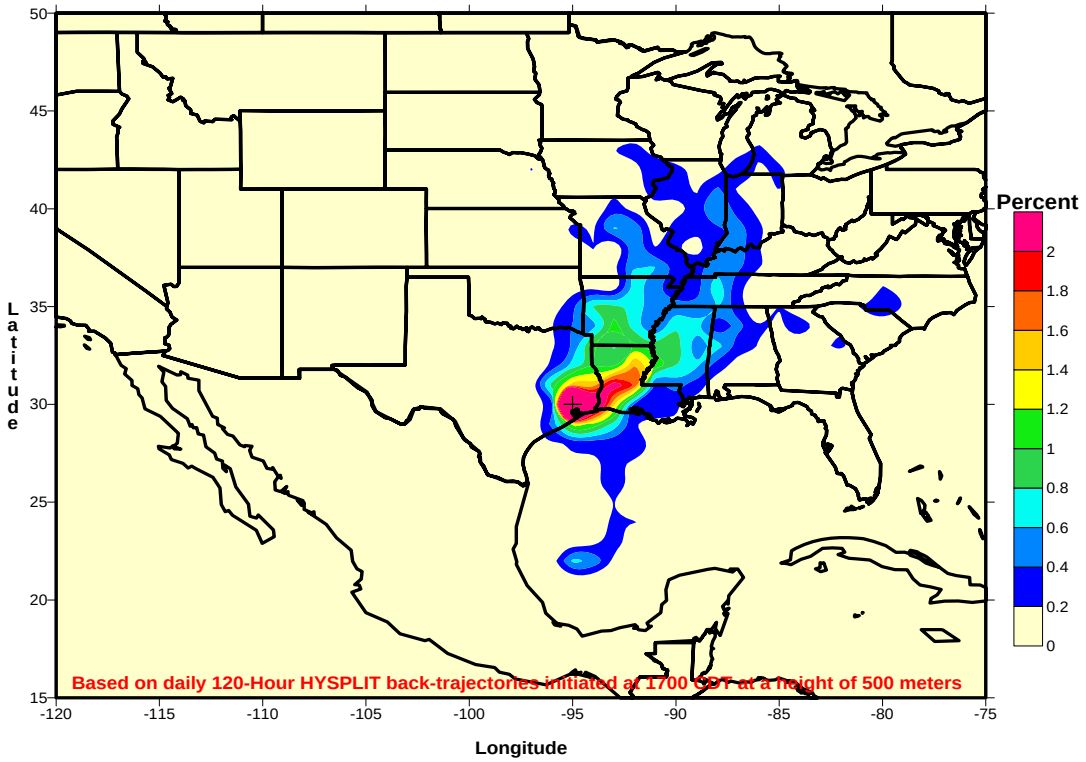
Trajectory Residence Time in Percent for Days with 8-Hour Ozone >= 75 ppb

Years 2001 - 2005: September; HOUSTON/GALVESTON/BRAZORIA



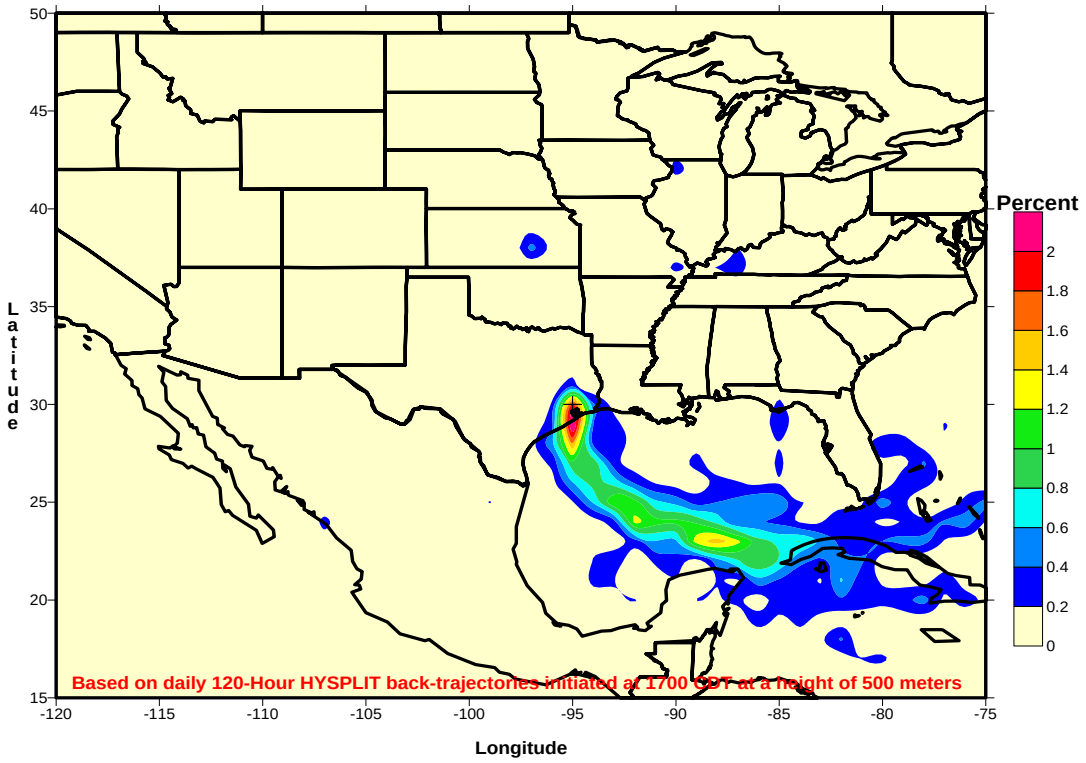
Trajectory Residence Time in Percent for Days with 8-Hour Ozone >= 85 ppb

Years 2001 - 2005: September; HOUSTON/GALVESTON/BRAZORIA



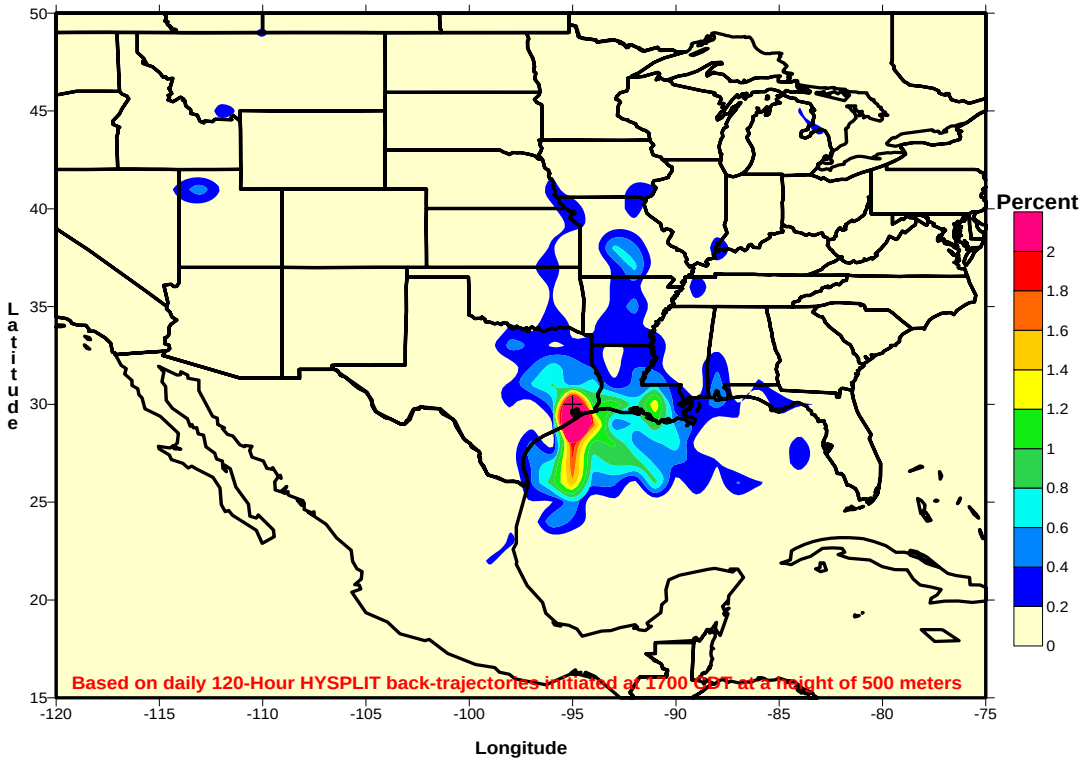
Trajectory Residence Time in Percent for the Lowest 20% 8-Hour Ozone Days

Years 2001 - 2005: April; HOUSTON/GALVESTON/BRAZORIA



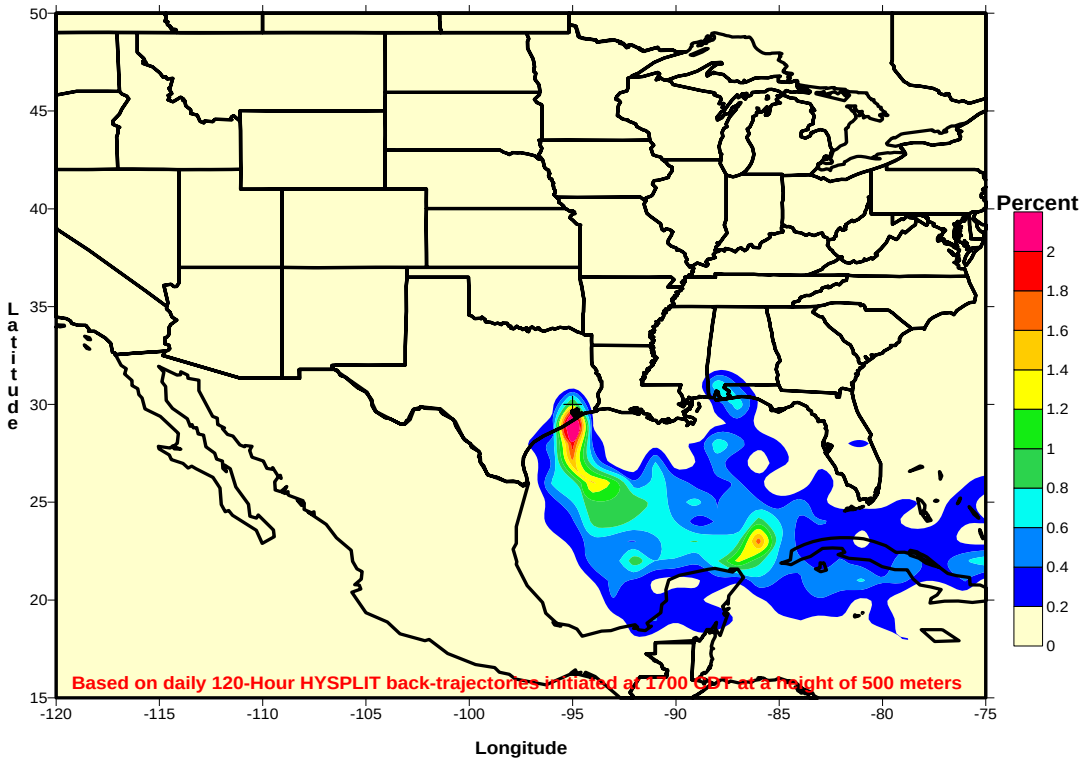
Trajectory Residence Time in Percent for the Top 20% 8-Hour Ozone Days

Years 2001 - 2005: April; HOUSTON/GALVESTON/BRAZORIA



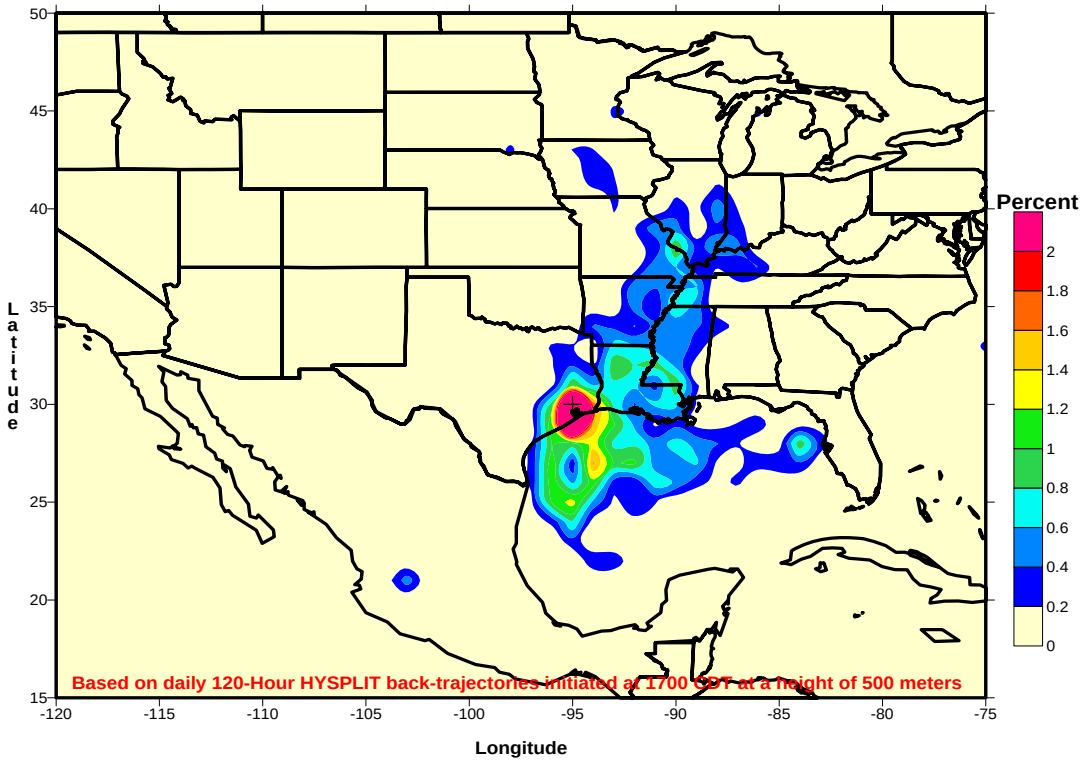
Trajectory Residence Time in Percent for the Lowest 20% 8-Hour Ozone Days

Years 2001 - 2005: May; HOUSTON/GALVESTON/BRAZORIA



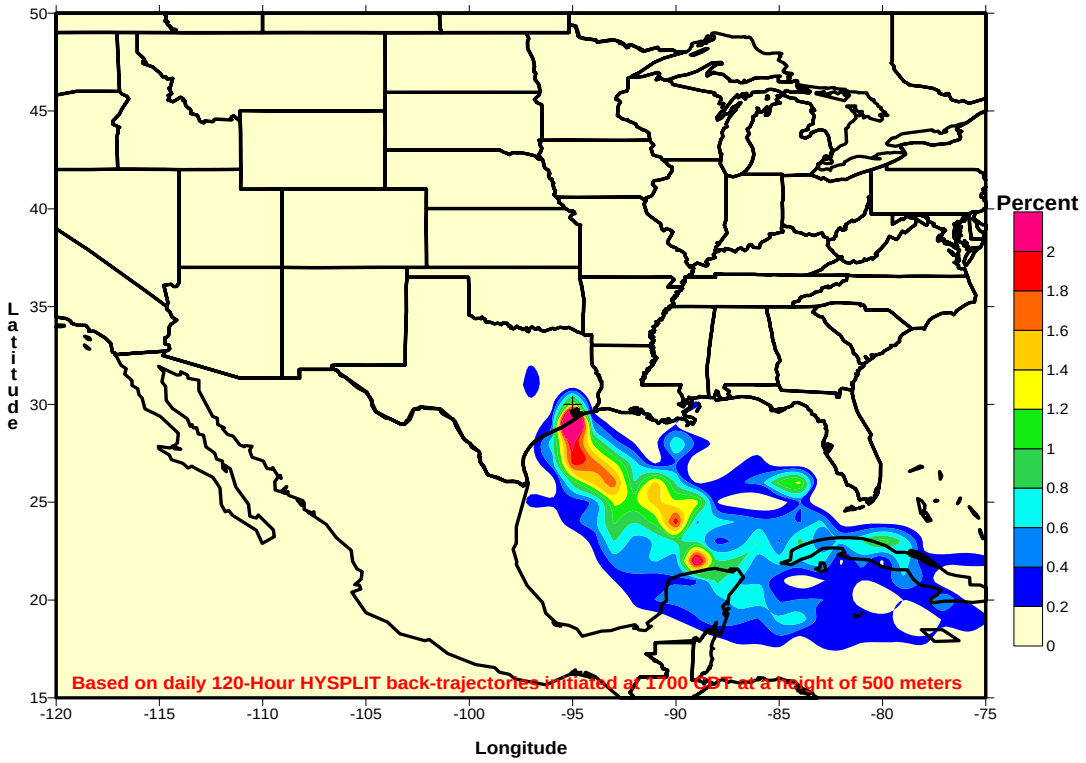
Trajectory Residence Time in Percent for the Top 20% 8-Hour Ozone Days

Years 2001 - 2005: May; HOUSTON/GALVESTON/BRAZORIA



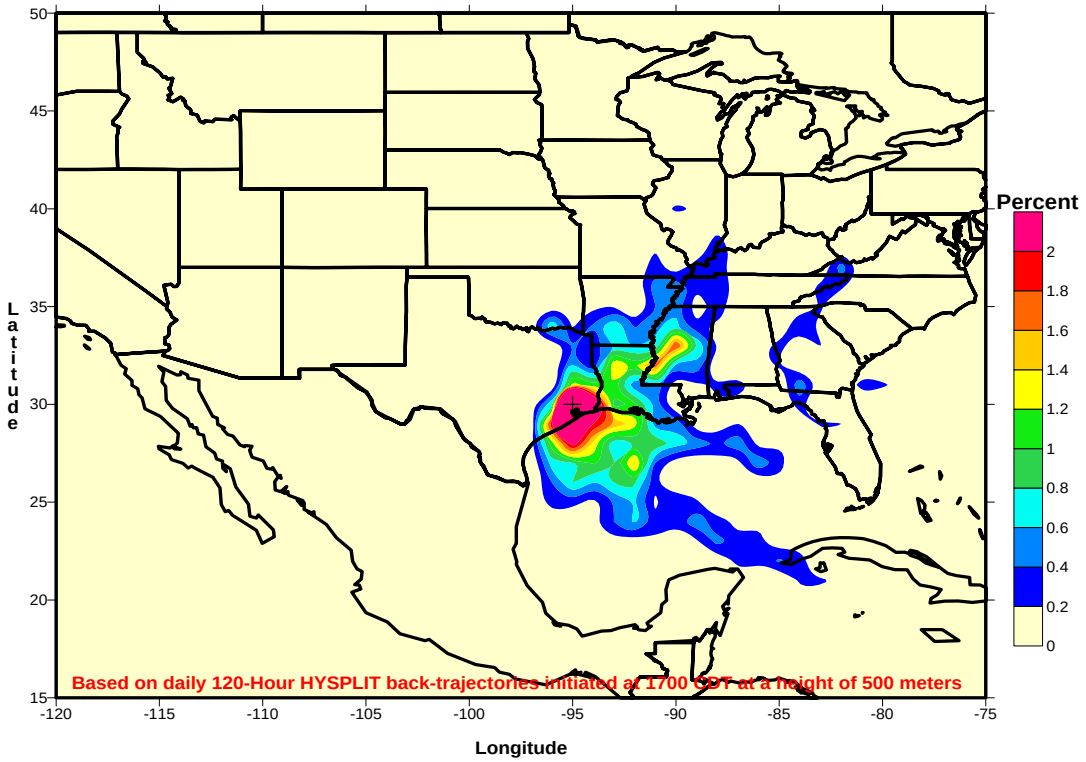
Trajectory Residence Time in Percent for the Lowest 20% 8-Hour Ozone Days

Years 2001 - 2005: June; HOUSTON/GALVESTON/BRAZORIA



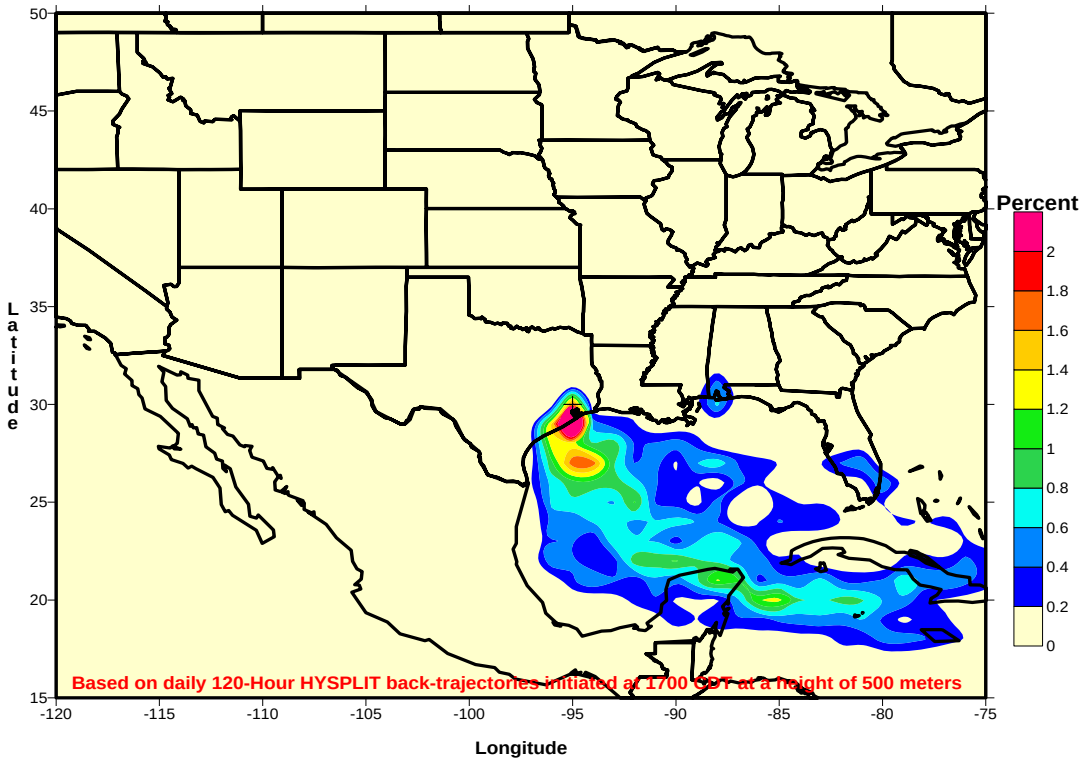
Trajectory Residence Time in Percent for the Top 20% 8-Hour Ozone Days

Years 2001 - 2005: June; HOUSTON/GALVESTON/BRAZORIA



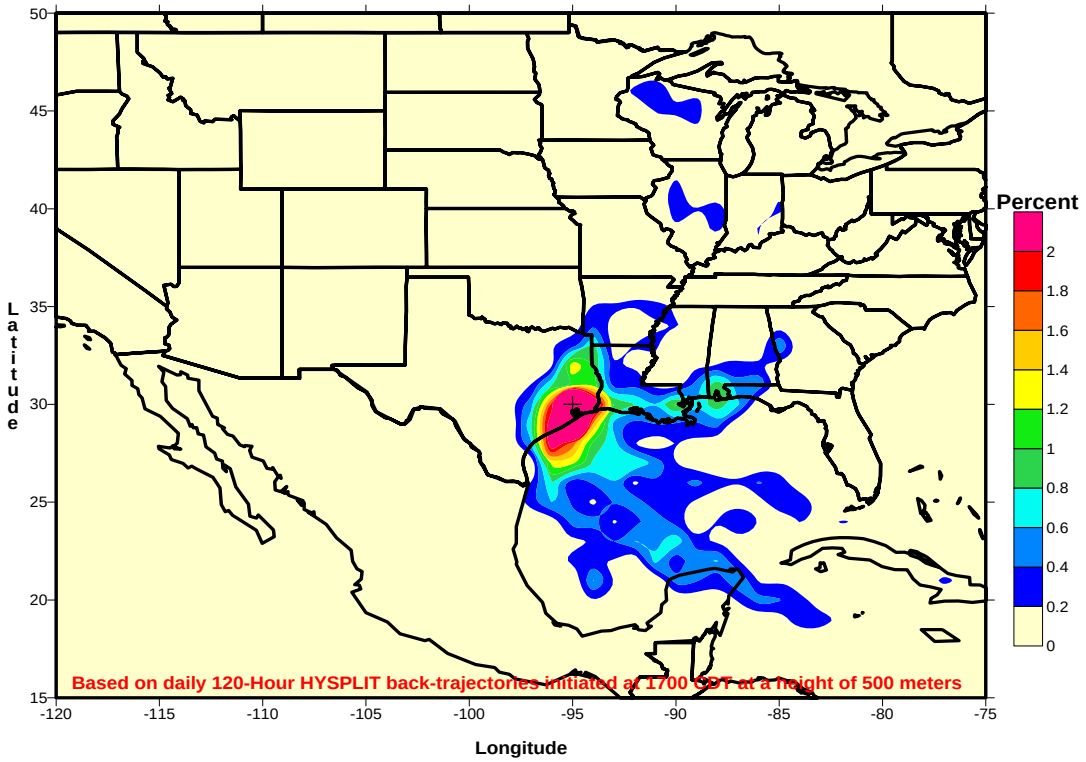
Trajectory Residence Time in Percent for the Lowest 20% 8-Hour Ozone Days

Years 2001 - 2005: July; HOUSTON/GALVESTON/BRAZORIA



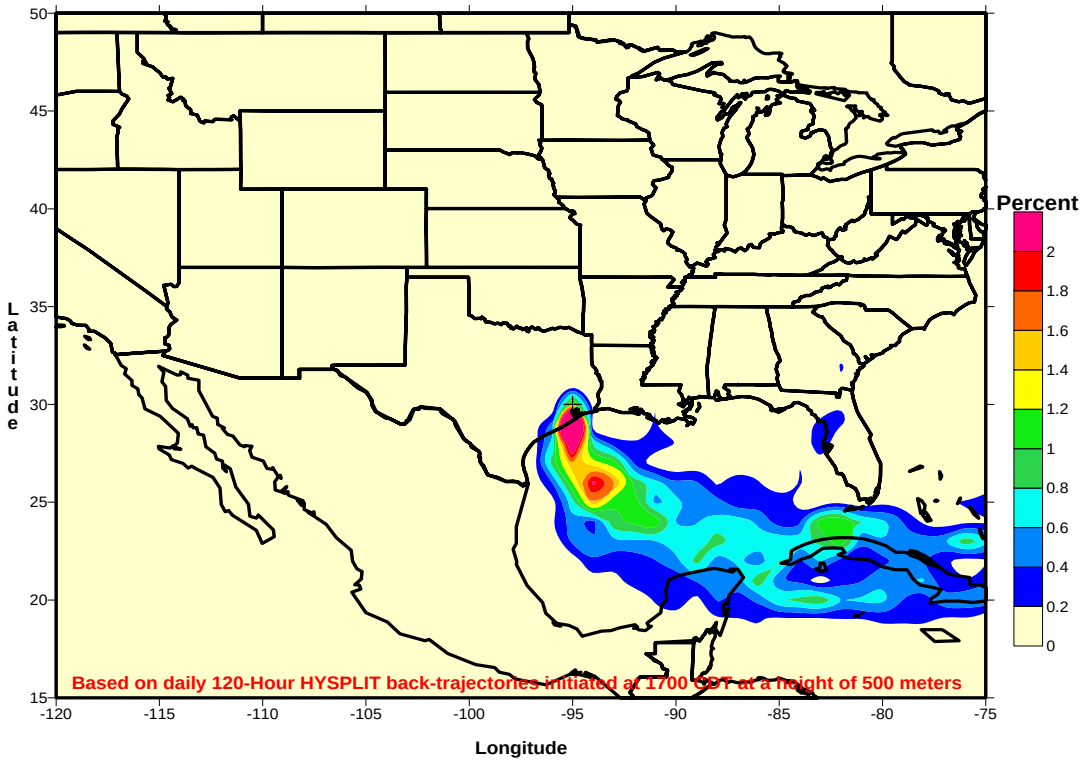
Trajectory Residence Time in Percent for the Top 20% 8-Hour Ozone Days

Years 2001 - 2005: July; HOUSTON/GALVESTON/BRAZORIA



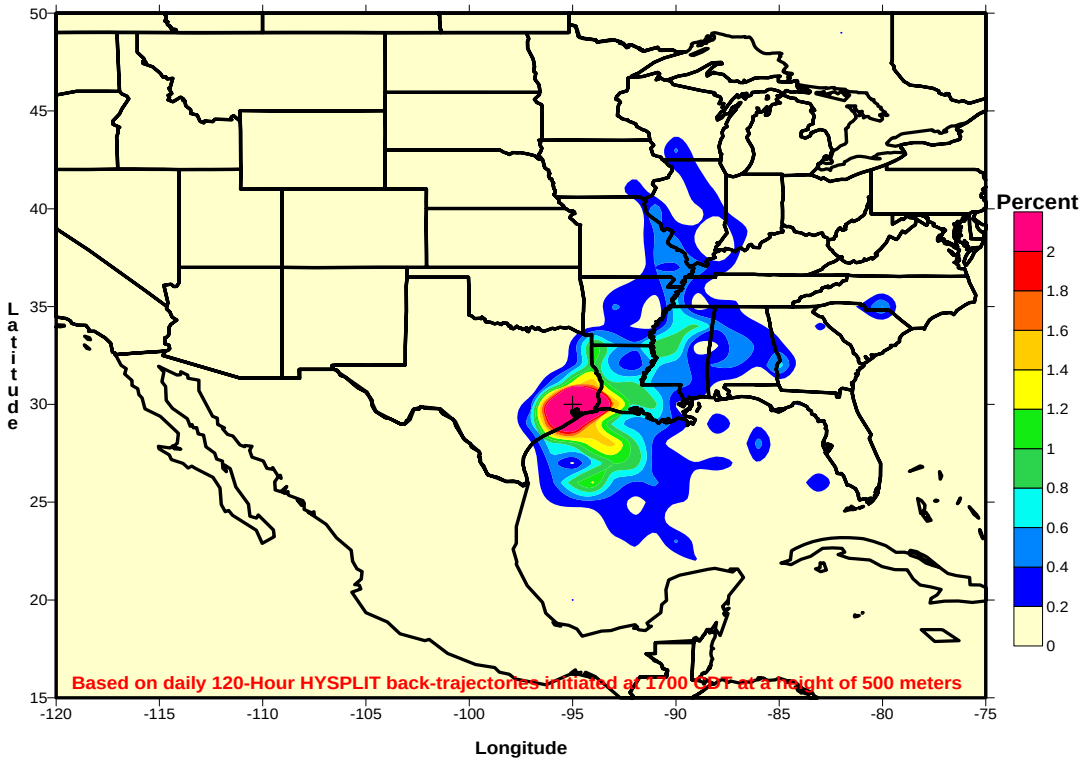
Trajectory Residence Time in Percent for the Lowest 20% 8-Hour Ozone Days

Years 2001 - 2005: August; HOUSTON/GALVESTON/BRAZORIA



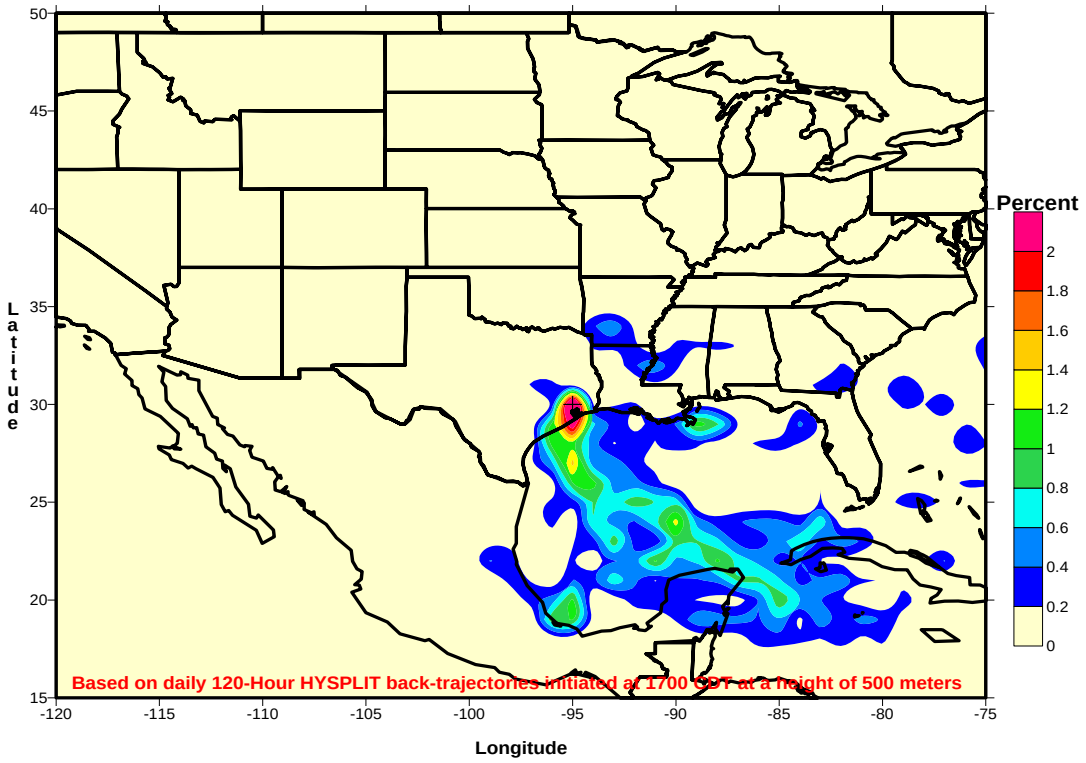
Trajectory Residence Time in Percent for the Top 20% 8-Hour Ozone Days

Years 2001 - 2005: August; HOUSTON/GALVESTON/BRAZORIA



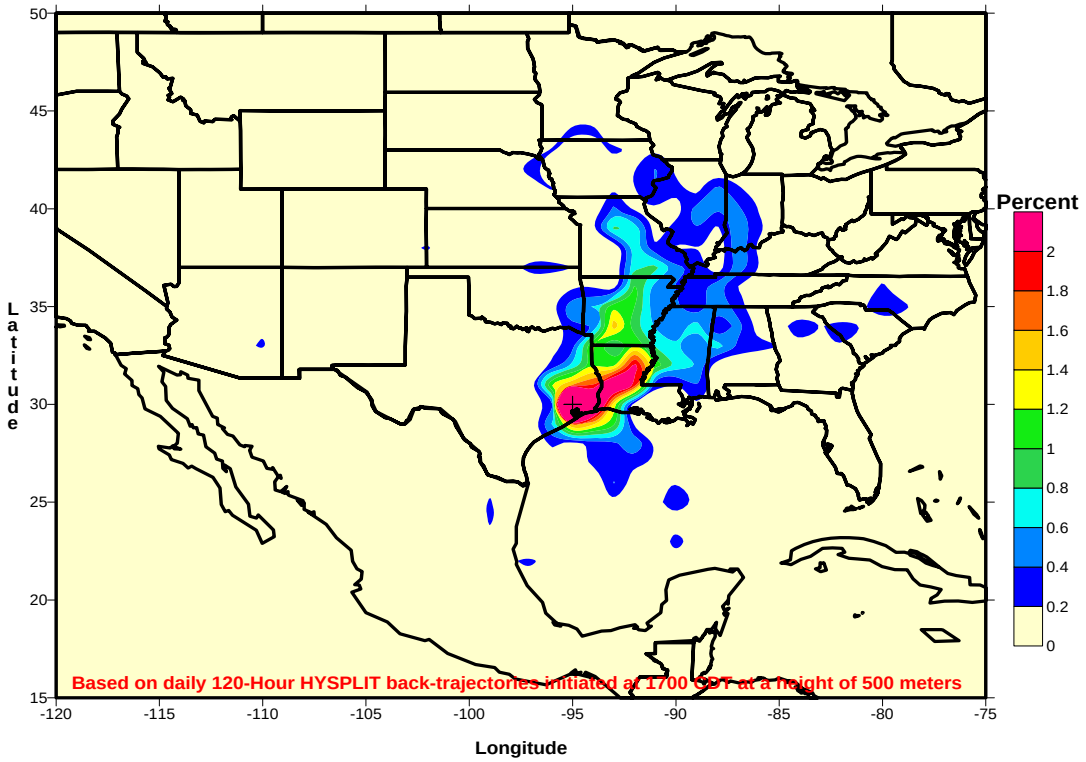
Trajectory Residence Time in Percent for the Lowest 20% 8-Hour Ozone Days

Years 2001 - 2005: September; HOUSTON/GALVESTON/BRAZORIA



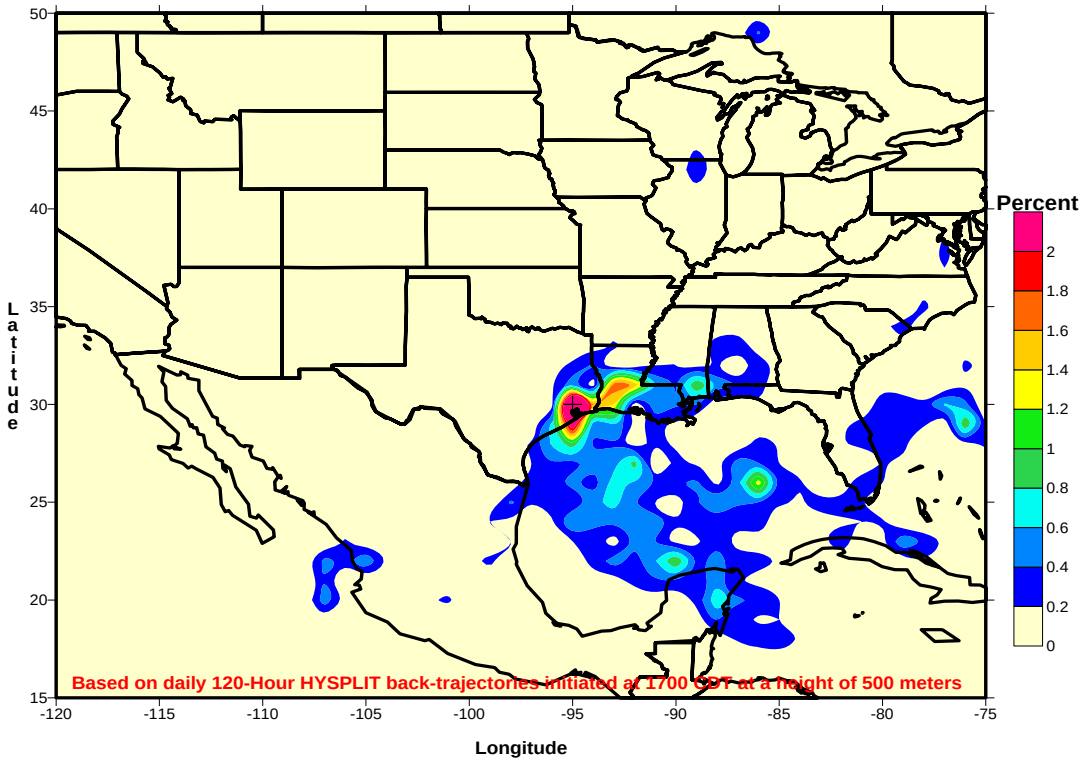
Trajectory Residence Time in Percent for the Top 20% 8-Hour Ozone Days

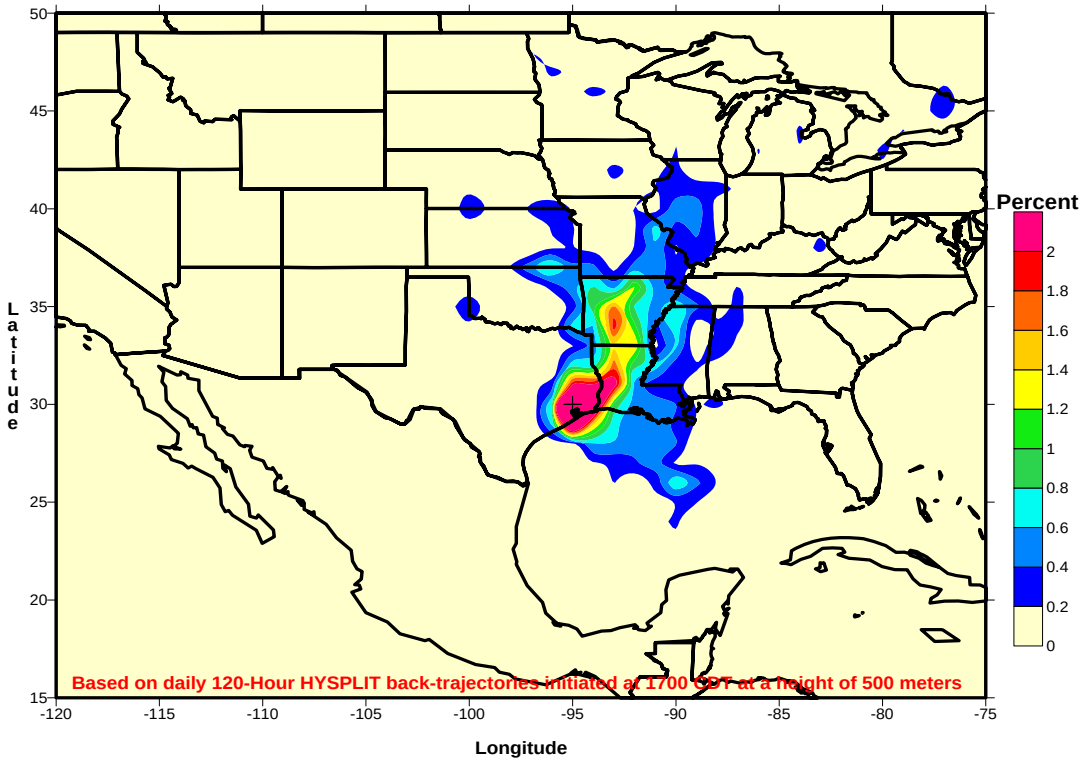
Years 2001 - 2005: September; HOUSTON/GALVESTON/BRAZORIA



Trajectory Residence Time in Percent for the Lowest 20% 8-Hour Ozone Days

Years 2001 - 2005: October; HOUSTON/GALVESTON/BRAZORIA



Trajectory Residence Time in Percent for the Top 20% 8-Hour Ozone Days

Years 2001 - 2005: October; HOUSTON/GALVESTON/BRAZORIA