Revision of the VISTAS 2002 Emissions Inventory for Aircraft, Locomotives, and Commercial Marine Vessels

A preliminary 2002 emissions inventory for aircraft, locomotives, and commercial marine vessels was prepared for VISTAS in early 2004. The methods used to develop the inventory are presented in a February 9, 2004 report "*Development of the VISTAS Draft 2002 Mobile Source Emission Inventory (February 2004 Version)*" as prepared by E.H. Pechan & Associates, Inc. A summary of the preliminary 2002 emissions inventory in presented in Table 1. Except as otherwise stated below, all aspects of the preparation methodology continue to apply to the revised emissions inventory presented herein.

Revisions to the preliminary 2002 emissions inventory were implemented to ensure that the latest state and local data were incorporated as well as to correct an overestimation of particulate matter (PM) emissions from aircraft. Seven of the ten VISTAS states provided revised inventory data in the form of emissions reported to the U.S. Environmental Protection Agency (EPA) under the Consolidated Emissions Reporting Rule (CERR). States providing CERR data were:

Alabama, Georgia, Mississippi, North Carolina,
Tennessee (excluding Davidson, Hamilton, Knox,
and Shelby Counties), Virginia, and West Virginia.

In many cases, the CERR data were only marginally different than the preliminary 2002 inventory data, but there were several instances where significant updates were evident. The remaining three VISTAS states, plus the portions of Tennessee excluded from the CERR data, indicated that the preliminary 2002 VISTAS inventory continued to reflect the most recent data available. These states were:

Florida, Kentucky, and South Carolina.

Florida did provide updated aircraft emissions data for one county (Miami-Dade) and these data were incorporated in the revised 2002 inventory as described below.

Since several states recommended retaining the preliminary 2002 inventory data, the initial step toward revising the 2002 inventory consisted of modifying the estimated aircraft PM emissions of the preliminary inventory. The overestimation of aircraft PM became evident shortly after the release of the preliminary 2002 inventory, when it was determined that VISTAS region airports would constitute the top seven, and 11 of the top 15, PM sources in the nation. Moreover, PM emissions for one airport (Miami International) were a full order of magnitude larger than *all* other elemental carbon PM emission sources. In addition, unexpected relationships across airports were also observed, with emissions for Atlanta's Hartsfield International being substantially less than those of Miami International, even though Atlanta handles over twice as many aircraft operations annually. Given the pervasiveness of this problem, and since the CERR data submitted by states was based on the preliminary 2002 VISTAS inventory data, aircraft PM emissions for the entire VISTAS region were recalculated.

Table 1. Preliminary 2002 Aircraft, Locomotive, and Non-Recreational Marine Emissions as Reported in February 2004 (annual tons)

Source	State	CO	NO_x	PM-10	PM-2.5	SO_2	VOC
Aircraft (2275)	AL	3,787	175	688	475	17	196
	FL	28,518	11,955	46,352	31,983	1,050	3,703
	GA	3,175	992	3,919	2,704	94	353
	KY	2,666	657	2,597	1,792	63	263
	MS	1,593	140	553	381	13	96
	NC	6,088	1,548	6,115	4,219	148	613
	SC	6,505	515	452	312	88	863
	TN	6,854	2,665	7,986	5,510	225	920
	VA	17,676	5,607	14,476	9,988	234	3,229
	WV	1,178	78	310	214	8	66
	Total	78,040	24,332	83,448	57,578	1,940	10,302
Commercial Marine (2280)	AL	1,195	9,217	917	843	3,337	736
	FL	5,888	44,817	1,936	1,781	6,683	1,409
	GA	1,038	7,874	334	307	1,173	246
	KY	6,607	50,267	2,246	2,066	9,608	1,569
	MS	5,687	43,233	1,903	1,750	7,719	1,351
	NC	599	4,547	193	178	690	142
	SC	1,067	8,100	343	316	1,205	253
	TN	4,129	31,397	1,390	1,278	5,753	980
	VA	1,198	3,426	929	855	3,258	596
	WV	2,094	15,882	668	614	720	497
	Total	29,503	218,760	10,858	9,989	40,146	7,779
Military Marine (2283)	VA	136	387	28	26	30	59
	Total	136	387	28	26	30	59
Locomotives (2285)	AL	3,490	26,339	592	533	1,446	1,354
	FL	1,006	9,969	247	222	605	404
	GA	2,654	26,733	664	598	1,622	1,059
	KY	2,166	21,811	542	488	1,321	867
	MS	2,302	23,267	578	520	1,429	899
	NC	1,638	16,502	410	369	1,001	654
	SC	1,160	11,690	291	261	710	462
	TN	4,530	44,793	1,110	999	2,689	1,805
	VA	1,928	19,334	1,407	1,266	3,443	798
	WV	1,105	11,150	277	249	681	436
	Total	21,980	211,588	6,118	5,505	14,947	8,738
Grand Total		129,659	455,067	100,452	73,099	57,062	26,877

Aircraft do emit PM while operating. However, official EPA inventory procedures for aircraft generally do not include PM emission factors and, therefore, aircraft PM is generally erroneously reported as zero. In an effort to overcome this deficiency, the developers of the preliminary VISTAS 2002 aircraft inventory estimated PM emission rates for aircraft using estimated NO_x emissions and an unreported PM-to-NO_x ratio (i.e., PM = NO_x times a PM-to-NO_x ratio). According to the preliminary inventory documentation, this approach was applied only to commercial aircraft NO_x, but a review of the preliminary inventory indicates that the technique was also applied to military, general aviation, and air taxi aircraft in many, but not all, instances. Although there is nothing inherently incorrect with this approach, the accuracy and inconsistent application of the assumed PM-to-NO_x ratio results in grossly overestimated aircraft PM.

Through examination of the preliminary 2002 aircraft inventory, it is apparent that the commercial aircraft PM-to-NO_x ratio used to generate PM emission estimates was approximately equal to 3.95 (i.e., PM = NO_x times 3.95). While the majority of observed commercial aircraft PM-to-NO_x ratios in the preliminary inventory are equal to 3.95, a few range as low as 3.00. If all aircraft estimates are included (i.e., commercial plus military, general aviation, and air taxi), observed PM-to-NO_x ratios range from 0 to 123.0, and average 3.43 as illustrated in the following inventory statistics:

Aircraft Type	Average PM-to-NO_x	Range of PM-to-NO_x	Average PM-2.5/PM-10	Range of PM-2.5/PM-10
Undefined (1)	0.046	0-0.062	0.690	0.690-0.690
Military	0.073	0-92.3	0.688	0.333-1.000
Commercial	3.953	3.00-3.953	0.690	0.667-0.696
General Aviation	2.059	0-9.00	0.689	0.500-1.000
Air Taxi	2.734	0-123.0	0.690	0.500-1.000
Aggregate	3.427	0-123.0	0.690	0.333-1.000

(1) Two counties report aircraft emissions as SCC 2275000000 “all aircraft.”

As indicated, the aggregate PM-to-NO_x ratio is similar in magnitude to the ratio for commercial aircraft. This results from the dominant nature of commercial aircraft NO_x emissions relative to NO_x from other aircraft types. It is surmised that ratios that deviate from 3.95 are based on PM emission estimates generated by local planners, which were retained without change in the PM estimation process (although a considerable number of unexplained “zero PM” records also exist in the preliminary inventory dataset). Regardless, based on previous statistical analyses performed in support of aircraft emissions inventory development outside the VISTAS region, a PM-to-NO_x ratio of 3.95 is too large by over an order of magnitude.

Based on analyses performed for the Tucson, Arizona planning area, PM-to-NO_x ratios for aircraft over a standard aircraft landing and takeoff (LTO) cycle are estimated to be as follows:[1]

[1] See, “*Emissions Inventories for the Tucson Air Planning Area, Volume I., Study Description and Results*,” prepared for the Pima Association of Governments, Tucson, AZ, November 2001.

Aircraft Type	PM-to-NO_x [2]
Commercial Aircraft	0.26
Military Aircraft	0.88
Air Taxi Aircraft	0.50
General Aviation Aircraft	1.9

In reviewing these data, it should be considered that they apply to a standard (i.e., EPA-defined) LTO cycle. Aircraft PM-to-NO_x ratios vary with operating mode, so that aircraft at airports with mode times that differ from the standard cycle will exhibit varying ratios. However, conducting an airport-specific analysis for all airports in the VISTAS region is beyond the scope of this work. While local PM-to-NO_x ratios could vary somewhat from the indicated standard cycle ratios, any error due to this variation will be significantly less than the order of magnitude error associated with the 3.95 commercial aircraft ratio used for the preliminary 2002 inventory.

It should be recognized that while the Tucson area is far removed from the VISTAS region, the data analyzed to generate the PM-to-NO_x ratios is standard aircraft emission factor data routinely employed for inventory purposes throughout the U.S. With the exception of aircraft operating conditions, there are no inherent geographic implications associated with the use of data from the Tucson study. As indicated above, issues associated with local operating conditions have been eliminated by recalculating the Tucson study ratios for a standard LTO cycle.

To implement the revised PM-to-NO_x ratios, *all* aircraft PM records were removed from the 2002 preliminary inventory.[3] In undertaking this removal, it became apparent that there was an imbalance in the aircraft NO_x and PM records in the preliminary 2002 inventory. Whereas there were 1,531 NO_x records, there were only 1,212 PM records. The imbalance was distributed between three states, South Carolina, Tennessee, and Virginia as follows:

Aircraft NO_x records with no corresponding PM record:

Aircraft Type	South Carolina	Virginia	Total
Military Aircraft	8	100	108
General Aviation Aircraft	14	94	108
Air Taxi Aircraft	5	99	104
Aggregate	27	293	320

[2] The PM and NO_x emission estimates presented in the Tucson study are for local aircraft operating mode times. For this work, emission estimates for Tucson were recalculated for a standard LTO cycle, so that the ratios presented are applicable to the standard LTO cycle and not a Tucson-specific cycle. Thus, the ratios presented herein vary somewhat from those associated with the emission estimates presented in the Tucson study report.

[3] This includes even records for which local planners may have estimated PM emissions. This approach was taken for two reasons. First, there is no way to distinguish which records may have been generated by local planners. Second, the data available to local planners is no better than that used to generate the presented PM-to-NO_x ratio data, so the consistent application of these data to the entire VISTAS region is the most appropriate approach to generating consistent inventories throughout the region.

Aircraft PM records with no corresponding NO_x record:

Aircraft Type	Tennessee	Total
Air Taxi Aircraft	1	1
Aggregate	1	1

The unmatched PM record was for Hamilton County (Chattanooga), Tennessee and when removed, was not replaced since there was no corresponding NO_x record with which to estimate revised PM emissions. It is unclear how this orphaned record originated, but clearly than can be no air taxi PM emissions without other combustion-related emissions. Thus, the removal of the PM-10 and PM-2.5 records for Hamilton County permanently reduced the overall size of the 2002 preliminary inventory database by two records.

Of the 320 unmatched NO_x records, 269 were records for which the reported emission rate was zero. Therefore, even though associated PM records were missing, the overall inventory was not affected. However, the 51 missing records for which NO_x emissions were non-zero, do impact PM estimates for the overall inventory.

The preliminary 2002 inventory had 20,503 records prior to the aircraft PM recalculation. This was reduced by 1,212 with the removal of all aircraft PM-10 records and by another 1,212 with the removal of all aircraft PM-2.5 records, so that there were 18,079 records prior to the addition of replacement PM records. Replacement PM-10 records were calculated for all 1,531 aircraft NO_x records using the PM-to-NO_x ratios presented above. Aircraft type-specific ratios were utilized in all cases, except for two counties where aircraft emissions were reported under the generic aircraft SCC 2275000000. For these counties (Palm Beach County, Florida and Davidson County, Tennessee), the commercial aircraft PM-to-NO_x ratio was applied since both contain commercial airports (Palm Beach International and Nashville International) which undoubtedly were responsible for the bulk of reported NO_x. The replacement aircraft PM-10 records added 1,531 records to the revised 2002 preliminary inventory, bring the total number of inventory records to 19,610.

Replacement aircraft PM-2.5 records were also developed. The preliminary 2002 inventory assumed that aircraft PM-2.5 was 69 percent of aircraft PM-10. The origin of this fraction is not clear, but it is very low for combustion related particulate. The majority of internal combustion engine related particulate is PM-1 or smaller, so that typical internal combustion engine PM-2.5 fractions approach 100 percent. For example, the EPA NONROAD model assumes 92 percent for gasoline engine particulate and 97 percent for diesel engine particulate. Based on recent correspondence from the EPA, it appears that the agency is preparing to recommend a PM-2.5 fraction of 98 percent for aircraft.[4] This is substantially more consistent with expectations based on emissions test data for other internal combustion engine sources, and was used as the basis for the recalculated aircraft PM-2.5 emission estimates in the revised 2002 preliminary inventory.

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[4] August 12, 2004 e-mail correspondence from EPA to Gregory Stella of Alpine Geophysics.

The addition of 1,531 recalculated PM-2.5 records brings to 21,141 the total number of records in the revised 2002 preliminary inventory database.

Although a substantial portion of the preliminary 2002 inventory was ultimately replaced with data prepared by state and local planners under CERR requirements, it was necessary to first revise the preliminary 2002 aircraft inventory as described so that that records extracted from the inventory for areas not relying on CERR data would be accurate. Therefore, in *no case* is the aggregated state data reported for the final 2002 inventory identical to that of the preliminary 2002 inventory. Even areas relying on the preliminary 2002 inventory will reflect updates due to changes in emissions of PM-10 and PM-2.5 from aircraft.

Table 2 presents the revised 2002 preliminary inventory estimates. These estimates do not reflect any changes related to updated CERR data, but instead indicate the impacts associated with the recalculation of aircraft PM emissions alone. Table 3 presents a summary of the net impacts of these changes, where an over 90 percent reduction in aircraft PM is observed for all VISTAS areas except South Carolina and Virginia. The reasons for the lesser changes in these two states is that the overall aircraft NO_x inventories for both include a large share of military aircraft NO_x to which no (or very low) particulate estimates were assigned in the preliminary 2002 inventory. Since these operations are assigned non-zero PM emissions under the revised approach, the increase in military aircraft PM offsets a portion of the reduction in commercial aircraft PM. In Virginia, zero (or near zero) PM military operations were responsible for about 35 percent of total aircraft NO_x, while the corresponding fraction in South Carolina was almost 70 percent. As indicated, aggregate aircraft, locomotive, and commercial marine vessel PM is 70-75 percent lower in the revised 2002 preliminary inventory.

As indicated above, for the final 2002 inventory, data for all or portions of seven states were replaced with corresponding data from recent CERR submissions for 2002. Before replacing these data, however, an analysis of the CERR data was performed to ensure consistency with VISTAS inventory methods.[5] Several important observations resulted from this analysis. First, it is clear that all of the CERR data continue to rely on the inaccurate aircraft PM estimation approach employed for the preliminary 2002 inventory. Therefore, an identical aircraft PM replacement procedure as described above for the preliminary inventory was undertaken. As a result, the CERR data for *all* states has been modified for inclusion in the final 2002 VISTAS inventory.

As was the case with the preliminary VISTAS inventory, there were a substantial number of aircraft NO_x records without corresponding PM records, so that the number of recalculated PM records added to the CERR dataset is greater than the number of PM records removed. The aggregated CERR inventory data, reflecting data for all or parts of seven states, consisted of 13,656 records, of which 1,211 were aircraft NO_x records. However, the number of corresponding aircraft PM records was 662 (662 PM-10 records and 662 PM-2.5 records). This imbalance was distributed as follows:

[5] It should perhaps also be noted that three of the CERR datasets provided for the final inventory (specifically those for Tennessee, Virginia, and West Virginia) included both annual and daily emissions data. Only the annual data were used for the final VISTAS inventory.

Table 2. Preliminary 2002 Aircraft, Locomotive, and Non-Recreational Marine Emissions with Modified Aircraft PM Emission Rates (annual tons)

Source	State	CO	NO_x	PM-10	PM-2.5	SO_2	VOC
Aircraft (2275)	AL	3,787	175	64	62	17	196
	FL	28,518	11,955	3,193	3,129	1,050	3,703
	GA	3,175	992	269	264	94	353
	KY	2,666	657	179	175	63	263
	MS	1,593	140	44	43	13	96
	NC	6,088	1,548	419	411	148	613
	SC	6,505	515	409	401	88	863
	TN	6,854	2,665	707	692	225	920
	VA	17,676	5,607	2,722	2,667	234	3,229
	WV	1,178	78	25	24	8	66
	Total	78,040	24,332	8,030	7,870	1,940	10,302
Commercial Marine (2280)	AL	1,195	9,217	917	843	3,337	736
	FL	5,888	44,817	1,936	1,781	6,683	1,409
	GA	1,038	7,874	334	307	1,173	246
	KY	6,607	50,267	2,246	2,066	9,608	1,569
	MS	5,687	43,233	1,903	1,750	7,719	1,351
	NC	599	4,547	193	178	690	142
	SC	1,067	8,100	343	316	1,205	253
	TN	4,129	31,397	1,390	1,278	5,753	980
	VA	1,198	3,426	929	855	3,258	596
	WV	2,094	15,882	668	614	720	497
	Total	29,503	218,760	10,858	9,989	40,146	7,779
Military Marine (2283)	VA	136	387	28	26	30	59
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Locomotives (2285)	AL	3,490	26,339	592	533	1,446	1,354
	FL	1,006	9,969	247	222	605	404
	GA	2,654	26,733	664	598	1,622	1,059
	KY	2,166	21,811	542	488	1,321	867
	MS	2,302	23,267	578	520	1,429	899
	NC	1,638	16,502	410	369	1,001	654
	SC	1,160	11,690	291	261	710	462
	TN	4,530	44,793	1,110	999	2,689	1,805
	VA	1,928	19,334	1,407	1,266	3,443	798
	WV	1,105	11,150	277	249	681	436
	Total	21,980	211,588	6,118	5,505	14,947	8,738
Grand Total		129,659	455,067	25,034	23,390	57,062	26,877

Table 3. Change in Preliminary 2002 Emissions due to Aircraft PM Emission Rate Modification

Source	State	CO	NO_x	PM-10	PM-2.5	SO_2	VOC
Aircraft (2275)	AL	0%	0%	-91%	-87%	0%	0%
	FL	0%	0%	-93%	-90%	0%	0%
	GA	0%	0%	-93%	-90%	0%	0%
	KY	0%	0%	-93%	-90%	0%	0%
	MS	0%	0%	-92%	-89%	0%	0%
	NC	0%	0%	-93%	-90%	0%	0%
	SC	0%	0%	-9%	+29%	0%	0%
	TN	0%	0%	-91%	-87%	0%	0%
	VA	0%	0%	-81%	-73%	0%	0%
	WV	0%	0%	-92%	-89%	0%	0%
	Total	0%	0%	-90%	-86%	0%	0%
Commercial Marine (2280)	AL	0%	0%	0%	0%	0%	0%
	FL	0%	0%	0%	0%	0%	0%
	GA	0%	0%	0%	0%	0%	0%
	KY	0%	0%	0%	0%	0%	0%
	MS	0%	0%	0%	0%	0%	0%
	NC	0%	0%	0%	0%	0%	0%
	SC	0%	0%	0%	0%	0%	0%
	TN	0%	0%	0%	0%	0%	0%
	VA	0%	0%	0%	0%	0%	0%
	WV	0%	0%	0%	0%	0%	0%
	Total	0%	0%	0%	0%	0%	0%
Military Marine (2283)	VA	0%	0%	0%	0%	0%	0%
	Total	0%	0%	0%	0%	0%	0%
Locomotives (2285)	AL	0%	0%	0%	0%	0%	0%
	FL	0%	0%	0%	0%	0%	0%
	GA	0%	0%	0%	0%	0%	0%
	KY	0%	0%	0%	0%	0%	0%
	MS	0%	0%	0%	0%	0%	0%
	NC	0%	0%	0%	0%	0%	0%
	SC	0%	0%	0%	0%	0%	0%
	TN	0%	0%	0%	0%	0%	0%
	VA	0%	0%	0%	0%	0%	0%
	WV	0%	0%	0%	0%	0%	0%
	Total	0%	0%	0%	0%	0%	0%
Grand Total		0%	0%	-75%	-68%	0%	0%

CERR Aircraft NO_x records with no corresponding PM record:

Aircraft Type	Georgia	Tennessee	Virginia	Total
Military Aircraft			136	136
Commercial Aircraft		4	136	140
General Aviation Aircraft	1		136	137
Air Taxi Aircraft			136	136
Aggregate	1	4	544	549

From this tabulation, it is clear that virtually the entire imbalance is associated with the Virginia CERR submission, with minor imbalances in Georgia and Tennessee. Of the 549 unmatched NO_x records, 461 were records for which the reported emission rate was zero. Therefore, even though the associated PM records were missing, the overall inventory was not affected. However, the 88 missing records for which NO_x emissions were non-zero, do impact PM emission estimates for the overall inventory.

Replacement aircraft PM records (both PM-10 and PM-2.5) were generated for the CERR dataset using procedures identical to those described above for the preliminary 2002 inventory. On this basis, the original 13,656 record dataset was reduced in size through the removal of 662 aircraft PM-10 records and 662 aircraft PM-2.5 records. The resulting 12,332 CERR records were then supplemented through the addition of 1,211 replacement PM-10 and 1,211 replacement PM-2.5 records, bringing the PM-adjusted dataset to 14,754 records.

Further analysis revealed that the CERR data for Virginia included only VOC, CO, and NO_x emissions for all aircraft, locomotives, and non-recreational marine vessels. Since SO_2, PM-10, and PM-2.5 records are included in the 2002 VISTAS inventory, an estimation method was developed for these emission species and applied to the Virginia CERR data. For PM, the developed methodology was only employed for locomotive and marine vessel data since aircraft PM was estimated using the PM-to-NO_x ratio methodology described above.

Consideration was given to simply adding the Virginia SO_2 and non-aircraft PM records from the revised preliminary 2002 VISTAS dataset, but it is very unlikely that either the source distribution or associated emission rates are identical across the CERR and preliminary VISTAS inventories. This was confirmed through a comparative analysis of dataset CO records. Therefore, an estimation methodology was developed using Virginia source-specific SO_2/CO, PM-10/CO, and PM-2.5/PM-10 ratios from the 2002 preliminary VISTAS inventory. The calculated ratios were then applied to the source-specific CERR CO emission estimates to derive associated source-specific SO_2, PM-10, and PM-2.5 emissions.

Initially, the development of the emissions ratios from the 2002 preliminary inventory was performed at the state (i.e., Virginia), county, and SCC level of detail. However, it readily became clear that there were substantial inconsistencies in ratios for identical SCCs across counties. For example, in one county, the SO_2/CO ratio might be 0.2, while in the next county it would be 2.0. Since the sources in question are virtually identical (e.g., diesel locomotives) and since the fueling infrastructure for these large nonroad equipment sources is regional as opposed to local in nature, such variations in emission rates are not realistic. Therefore, a more aggregated approach was employed in which SCC-specific emission ratios were developed for the state as a whole. Through this approach county-to-county variation is eliminated, but the underlying variation does continue to influence the resulting aggregate emission estimates (but across all counties equally). The calculated emission ratios are as follows:

Source	SCC	SO2/CO	PM10/CO	PM25/CO	PM25/PM10
Military Aircraft	2275001000	0.0215	*Emissions estimated using PM-to-NO_x ratios as described previously.*		
Commercial Aircraft	2275020000	0.3292			
General Aviation Aircraft	2275050000	0.0002			
Air Taxi Aircraft	2275060000	0.0015			
Aircraft Refueling	2275900000	0.0000	0.0000	0.0000	
Diesel Commercial Marine	2280002000	0.3697	0.3434	0.3157	0.92
Residual Commercial Marine	2280003000	0.3697	0.3434	0.3157	0.92
Diesel Military Marine	2283002000	0.2422	0.2248	0.2068	0.92
Line Haul Locomotives	2285002005	3.2757	1.2999	1.1696	0.90
Yard Locomotives	2285002010	2.2908	1.2461	1.1205	0.90

Through this process, an additional 680 non-aircraft SO_2, 680 non-aircraft PM-10, 680 non-aircraft PM-2.5, and 544 aircraft SO_2 emission estimates were developed for Virginia. These additional 2,548 records brought the overall CERR dataset size to 17,338 records.

It is important to recognize that the inconsistency of emissions ratios across Virginia counties for sources of virtually identical design, which utilize a regional rather than local fueling infrastructure, has potential implications for other VISTAS states. While it is beyond the scope of this work to conduct a quality assurance analysis for the emission inventory estimates for all states in the VISTAS region, there is no immediately obvious reason why such inconsistencies would be isolated to Virginia.

One final revision to the CERR dataset was undertaken, and that was the removal of two records for unpaved airstrip particulate (SCC 2275085000) in Alabama. Otherwise identical records for these emissions were reported both in terms of filterable and primary particulate. The filterable particulate records were removed as all other particulate emissions in the VISTAS inventories are in terms of primary particulate. This reduced the final CERR dataset size to 17,336 records. It is also perhaps worth noting that a series of 136 aircraft refueling records (SCC 2275900000) for Virginia were left in place, even through typically such emissions would be reported under SCC 2501080 in the area source inventory. If additional VISTAS aircraft refueling emissions are reported under SCC 2501080, then it may be desirable to recode these 136 records.

Finally, data for areas of the VISTAS region not represented in the CERR dataset were added to the CERR data by extracting the appropriate records from the revised preliminary 2002 inventory. Specifically, a total of 5,538 records applicable to the states of Florida, Kentucky, and South Carolina and the Tennessee counties of Davidson, Hamilton, Knox, and Shelby were extracted from the revised 2002 inventory and added to the CERR dataset, bringing the total number of dataset records to 22,874.

Following this aggregation, one last dataset revision was implemented. As indicated in the introduction of this section, preliminary 2002 emission estimates for Miami International Airport were determined to be excessive. Although the reason for this inaccuracy is not apparent, revised estimates for aircraft emissions in Miami-Dade County were obtained from Florida planners and used to overwrite the erroneous estimates from the preliminary inventory.[6]

Table 4 presents a summary of the resulting final VISTAS 2002 inventory estimates for aircraft, locomotives, and non-recreational marine vessels. Table 5 provides a comparison of the final inventory estimates to those of the preliminary 2002 inventory. As indicated, total emissions for VOC, CO, NO_x, and SO_2 are generally within 10 percent, but final PM emissions are reduced by 70-80 percent due to the approximate 90 percent reductions in aircraft PM estimates. In addition, the significant changes in Georgia aircraft emissions are due to the CERR correction of Atlanta Hartsfield International Airport emissions, which were significantly underestimated in the preliminary 2002 inventory. The reduction in Florida aircraft emissions due to the correction of Miami International estimates is also apparent.

Lastly, Table 6 provides a direct comparison of emission estimates from the preliminary and final 2002 inventories for all 16 VISTAS region airports with estimated annual NO_x emissions of 200 tons or greater. The table entries are sorted in order of decreasing NO_x and once again, the dramatic reduction in PM emissions is evident. However, in addition, the appropriate reversal of the relationship between Atlanta's Hartsfield and Miami International Airport is also depicted. As a rough method of quality assurance, Table 6 also includes a *gross* estimate of expected airport NO_x emissions using detailed NO_x estimates developed for Tucson International Airport in conjunction with the ratio of local to Tucson LTOs.[7] This is not meant to serve as anything other than a crude indicator of the propriety of the developed VISTAS estimates, and it is clear that the range of estimated-to-expected NO_x emissions has been substantially narrowed in the final 2002 inventory. Whereas estimated-to-expected ratios varied from about 0.2 to over 3.5 in the preliminary inventory, the range of variation is tightened on both ends, from about 0.5 to 1.75 for the final inventory. In effect, all estimates are now within a factor of two of the expected estimates, which is quite reasonable given likely variation in local and standard LTO cycles and variations in aircraft fleet mix across airports.

It is perhaps important to note that some shifting in county emissions assignments is evident between the preliminary and final aircraft inventories. For example, for the preliminary inventory, Atlanta Hartsfield estimates were assigned to Fulton County (FIP 13121), while they are assigned to Clayton County (FIP 13063) for the final inventory. Similarly, Dulles International Airport emissions were assigned solely to Fairfax County, Virginia (FIP 51059) in the preliminary inventory, but are split between Fairfax and Loudoun County (FIP 51107) for the final inventory. Such shifts reflect local planner decision-making and are not an artifact of the revisions described herein.

[6] Aircraft emission estimates were provided in an August 10, 2004 e-mail transmittal from Bruce Coward of Miami-Dade County to Martin Costello of the Florida Department of Environmental Protection.

[7] The Tucson NO_x estimates are revised to reflect a standard LTO cycle rather than the Tucson-specific LTO cycle. This should provide for a more realistic comparison to VISTAS estimates.

Table 4. Final 2002 Aircraft, Locomotive, and Non-Recreational Marine Emissions (annual tons)

Source	State	CO	NO_x	PM-10	PM-2.5	SO_2	VOC
Aircraft (2275)	AL	3,787	175	226	87	17	196
	FL	25,431	8,891	2,424	2,375	800	3,658
	GA	6,622	5,372	1,475	1,446	451	443
	KY	2,666	657	179	175	63	263
	MS	1,593	140	44	43	13	96
	NC	6,088	1,548	419	411	148	613
	SC	6,505	515	409	401	88	863
	TN	7,251	2,766	734	719	235	943
	VA	9,763	2,756	1,137	1,115	786	2,529
	WV	1,178	78	25	24	8	66
	Total	70,884	22,899	7,072	6,797	2,607	9,670
Commercial Marine (2280)	AL	1,196	9,218	917	844	3,337	737
	FL	5,888	44,817	1,936	1,781	6,683	1,409
	GA	1,038	7,875	334	307	1,173	246
	KY	6,607	50,267	2,246	2,066	9,608	1,569
	MS	5,688	43,233	1,903	1,751	7,719	1,351
	NC	599	4,547	193	178	690	142
	SC	1,067	8,100	343	316	1,205	253
	TN	3,624	27,555	1,217	1,120	4,974	860
	VA	972	2,775	334	307	359	483
	WV	1,528	11,586	487	448	525	362
	Total	28,207	209,972	9,911	9,118	36,275	7,413
Military Marine (2283)	VA	110	313	25	23	27	48
	Total	110	313	25	23	27	48
Locomotives (2285)	AL	3,490	26,339	592	533	1,446	1,354
	FL	1,006	9,969	247	222	605	404
	GA	2,725	27,453	682	614	1,667	1,086
	KY	2,166	21,811	542	488	1,321	867
	MS	2,302	23,267	578	520	1,429	899
	NC	1,638	16,502	410	369	1,001	654
	SC	1,160	11,690	291	261	710	462
	TN	2,626	25,627	633	570	1,439	1,041
	VA	1,186	11,882	1,529	1,375	3,641	492
	WV	1,311	13,224	329	296	808	517
	Total	19,611	187,764	5,833	5,248	14,066	7,777
Grand Total		118,812	420,948	22,841	21,186	52,976	24,908

Table 5. Change in 2002 Emissions, Final Inventory Relative to Preliminary Inventory

Source	State	CO	NO_x	PM-10	PM-2.5	SO_2	VOC
Aircraft (2275)	AL	0%	0%	-67%	-82%	0%	0%
	FL	-11%	-26%	-95%	-93%	-24%	-1%
	GA	+109%	+442%	-62%	-47%	+379%	+26%
	KY	0%	0%	-93%	-90%	0%	0%
	MS	0%	0%	-92%	-89%	0%	0%
	NC	0%	0%	-93%	-90%	0%	0%
	SC	0%	0%	-9%	+29%	0%	0%
	TN	+6%	+4%	-91%	-87%	+4%	+2%
	VA	-45%	-51%	-92%	-89%	+236%	-22%
	WV	0%	0%	-92%	-89%	0%	0%
	Total	-9%	-6%	-92%	-88%	+34%	-6%
Commercial Marine (2280)	AL	+0%	+0%	+0%	+0%	+0%	+0%
	FL	0%	0%	0%	0%	0%	0%
	GA	+0%	+0%	+0%	+0%	+0%	+0%
	KY	0%	0%	0%	0%	0%	0%
	MS	+0%	+0%	+0%	+0%	+0%	+0%
	NC	+0%	+0%	+0%	+0%	+0%	+0%
	SC	0%	0%	0%	0%	0%	0%
	TN	-12%	-12%	-12%	-12%	-14%	-12%
	VA	-19%	-19%	-64%	-64%	-89%	-19%
	WV	-27%	-27%	-27%	-27%	-27%	-27%
	Total	-4%	-4%	-9%	-9%	-10%	-5%
Military Marine (2283)	VA	-19%	-19%	-12%	-12%	-12%	-19%
	Total	-19%	-19%	-12%	-12%	-12%	-19%
Locomotives (2285)	AL	0%	0%	0%	0%	0%	0%
	FL	0%	0%	0%	0%	0%	0%
	GA	+3%	+3%	+3%	+3%	+3%	+3%
	KY	0%	0%	0%	0%	0%	0%
	MS	0%	0%	0%	0%	0%	0%
	NC	0%	0%	0%	0%	0%	0%
	SC	0%	0%	0%	0%	0%	0%
	TN	-42%	-43%	-43%	-43%	-46%	-42%
	VA	-38%	-39%	+9%	+9%	+6%	-38%
	WV	+19%	+19%	+19%	+19%	+19%	+19%
	Total	-11%	-11%	-5%	-5%	-6%	-11%
Grand Total		-8%	-7%	-77%	-71%	-7%	-7%

Table 6. Comparison of Airport Emissions (Airports with NO_x > 200 tons per year)

Airport	FIP	CO	NO_x	PM-10	PM-2.5	SO_2	VOC	Approx. LTOs	Predicted NO_x	VISTAS to Predicted
Preliminary 2002 Inventory										
Miami	12086	9,757	5,997	23,706	16,357	525	1,641	150,000	1,680	3.57
Orlando	12095	3,456	2,170	8,578	5,919	204	642	150,000	1,680	1.29
Memphis	47157	3,462	1,934	7,645	5,275	185	603	125,000	1,400	1.38
Reagan	51013	3,892	1,806	7,138	4,925	164	302	100,000	1,120	1.61
Hampton	51650	2,690	1,705	0	0	0	611	Military		
Dulles	51059	2,032	1,330	5,246	3,620	0	272	75,000	840	1.58
Orlando-Sanford	12117	3,615	1,225	4,837	3,337	100	351			
Atlanta	13121	1,457	913	3,608	2,490	86	274	420,000	4,704	0.19
Fort Lauderdale	12011	1,930	809	3,196	2,206	75	257	75,000	840	0.96
Charlotte	37119	1,643	788	3,113	2,148	75	255	150,000	1,680	0.47
Tampa	12057	1,399	785	3,101	2,140	74	240	75,000	840	0.93
Nashville	47037	1,819	653	40	28	33	239	60,000	672	0.97
Raleigh	37183	1,584	592	2,338	1,613	56	204	75,000	840	0.70
Louisville	21111	1,073	468	1,851	1,277	45	155	60,000	672	0.70
Jacksonville	12031	871	325	1,284	886	31	112	30,000	336	0.97
Palm Beach	12099	1,156	226	0	0	1	132	30,000	336	0.67
Aggregate		41,836	21,724	75,682	52,220	1,655	6,290			0.19-3.57
Final 2002 Inventory										
Atlanta	13063	4,121	5,288	1,435	1,406	443	337	420,000	4,704	1.12
Miami	12086	6,670	2,933	805	789	274	1,596	150,000	1,680	1.75
Orlando	12095	3,456	2,170	568	556	204	642	150,000	1,680	1.29
Memphis	47157	3,462	1,934	506	495	185	603	125,000	1,400	1.38
Orlando-Sanford	12117	3,615	1,225	338	332	100	351			
Fort Lauderdale	12011	1,930	809	217	212	75	257	75,000	840	0.96
Charlotte	37119	1,643	788	206	202	75	255	150,000	1,680	0.47
Tampa	12057	1,399	785	206	202	74	240	75,000	840	0.93
Nashville	47037	1,819	653	170	166	33	239	60,000	672	0.97
Reagan	51013	1,269	635	171	168	193	97	100,000	1,120	0.57
Dulles 1	51107	1,807	595	164	161	252	153	37,500	420	1.42
Raleigh	37183	1,584	592	156	153	56	204	75,000	840	0.70
Dulles 2	51059	1,095	591	156	153	252	115	37,500	420	1.41
Hampton	51650	858	535	471	461	18	305	Military		
Louisville	21111	1,073	468	123	121	45	155	60,000	672	0.70
Jacksonville	12031	871	325	87	85	31	112	30,000	336	0.97
Palm Beach	12099	1,156	226	59	58	1	132	30,000	336	0.67
Aggregate		37,829	20,550	5,838	5,721	2,312	5,793			0.47-1.75
Net Change		-10%	-5%	-92%	-89%	+40%	-8%			

Note: For the final inventory, Dulles International Airport emissions are split between two Virginia counties.

Predicted NO_x is based on the ratio of airport LTOs to test airport (Tucson International Airport) LTOs and NO_x. This is not a rigorous comparison, but rather an approximate indicator of expected magnitude.

VISTAS 2002, 2009, and 2018 Emissions Inventory for Aircraft, Locomotives, and Commercial Marine Vessels

Using the revised 2002 emissions inventory for aircraft, locomotives, and commercial marine vessels as described in the file named “Aircraft-Loco-CMV Revised 2002.doc” (transmitted via e-mail dated September 6, 2004), corresponding emissions inventories for 2009 and 2018 have been developed. This document describes the procedures employed in developing these inventories. The information presented is intended to build off of that presented in the September 6 document describing the 2002 inventory, so all tables and figures are numbered incrementally relative to the tables and figures in that document.

Following the transmission of the 2002 emissions inventory on September 6, it was discovered that there were 36 emissions inventory records for Georgia included in the CERR file provided by the U.S. EPA for Mississippi. It was confirmed that these same records were also included in the provided CERR file for Georgia, so that all 36 records were included in duplicate in the September 6, 2004 inventory for 2002. This was discovered prior to the “official” processing of the 2002 inventory by Mactec, but subsequent to the September 6, 2004 document describing the inventory procedures. As a result, the developed inventory is not affected, but two of the tables presented in the September 6 document (Tables 4 and 5) have minor inaccuracies. The original and revised versions of both tables are presented below. Additionally, Table 6 presents a summary of the duplicate records. All 2009 and 2018 emission forecasts are based on the revised 2002 data (i.e., the data without the duplicate records).

Although some of the data utilized has been updated, the methodology used to develop the 2009 and 2018 emissions forecasts for aircraft, locomotives, and commercial marine vessels (CMV) is identical to that used in the spring of 2004 to develop the preliminary 2018 Base 1 (“On the Books”) and 2018 Base 2 (“On the Way”) inventories. This methodology was described in two e-mails, sent on March 22, 2004 (Base 1) and April 9, 2004 (Base 2). Briefly, the methodology relies on growth and control factors developed from inventories used in support of recent EPA rulemakings, and consists of the following steps:

(a) Begin with the 2002 emission estimates for aircraft, locomotive, and CMV as described above (at the state-county-SCC-pollutant level of detail).

(b) Detailed inventory data (both before and after controls) for these same emission sources for 1996, 2010, 2015, and 2020 were obtained from the EPA's recent Clean Air Interstate Rule (CAIR) Technical Support Document. Using these data, combined growth and control factors for the period 2002-2009 and 2002-2018 are estimated using straight line interpolation between 1996 and 2010 (for 2002 and 2009) and 2105 and 2020 (for 2018). This is done at the state-county-SCC-pollutant level of detail.

(c) The EPA growth and control data are matched against the 2002 VISTAS data using state-county-SCC-pollutant as the match key. Ideally, there would be a one-to-one match and the process would end at this point. Unfortunately, actual match results are not ideal, so

Table 4. Final 2002 Aircraft, Locomotive, and Non-Recreational Marine Emissions (annual tons) -- *Original Table from September 6, 2004 Document*

Source	State	CO	NO_x	PM-10	PM-2.5	SO_2	VOC
Aircraft (2275)	AL	3,787	175	226	87	17	196
	FL	25,431	8,891	2,424	2,375	800	3,658
	GA	6,622	5,372	1,475	1,446	451	443
	KY	2,666	657	179	175	63	263
	MS	1,593	140	44	43	13	96
	NC	6,088	1,548	419	411	148	613
	SC	6,505	515	409	401	88	863
	TN	7,251	2,766	734	719	235	943
	VA	9,763	2,756	1,137	1,115	786	2,529
	WV	1,178	78	25	24	8	66
	Total	70,884	22,899	7,072	6,797	2,607	9,670
Commercial Marine (2280)	AL	1,196	9,218	917	844	3,337	737
	FL	5,888	44,817	1,936	1,781	6,683	1,409
	GA	1,038	7,875	334	307	1,173	246
	KY	6,607	50,267	2,246	2,066	9,608	1,569
	MS	5,688	43,233	1,903	1,751	7,719	1,351
	NC	599	4,547	193	178	690	142
	SC	1,067	8,100	343	316	1,205	253
	TN	3,624	27,555	1,217	1,120	4,974	860
	VA	972	2,775	334	307	359	483
	WV	1,528	11,586	487	448	525	362
	Total	28,207	209,972	9,911	9,118	36,275	7,413
Military Marine (2283)	VA	110	313	25	23	27	48
	Total	110	313	25	23	27	48
Locomotives (2285)	AL	3,490	26,339	592	533	1,446	1,354
	FL	1,006	9,969	247	222	605	404
	GA	2,725	27,453	682	614	1,667	1,086
	KY	2,166	21,811	542	488	1,321	867
	MS	2,302	23,267	578	520	1,429	899
	NC	1,638	16,502	410	369	1,001	654
	SC	1,160	11,690	291	261	710	462
	TN	2,626	25,627	633	570	1,439	1,041
	VA	1,186	11,882	1,529	1,375	3,641	492
	WV	1,311	13,224	329	296	808	517
	Total	19,611	187,764	5,833	5,248	14,066	7,777
Grand Total		118,812	420,948	22,841	21,186	52,976	24,908

Table 4. Final 2002 Aircraft, Locomotive, and Non-Recreational Marine Emissions (annual tons) -- *Revised Table (Changes in Red Font)*

Source	State	CO	NO_x	PM-10	PM-2.5	SO_2	VOC
Aircraft (2275)	AL	3,787	175	226	87	17	196
	FL	25,431	8,891	2,424	2,375	800	3,658
	GA	6,620	5,372	1,475	1,446	451	443
	KY	2,666	657	179	175	63	263
	MS	1,593	140	44	43	13	96
	NC	6,088	1,548	419	411	148	613
	SC	6,505	515	409	401	88	863
	TN	7,251	2,766	734	719	235	943
	VA	9,763	2,756	1,137	1,115	786	2,529
	WV	1,178	78	25	24	8	66
	Total	70,882	22,899	7,072	6,797	2,607	9,670
Commercial Marine (2280)	AL	1,196	9,218	917	844	3,337	737
	FL	5,888	44,817	1,936	1,781	6,683	1,409
	GA	1,038	7,875	334	307	1,173	246
	KY	6,607	50,267	2,246	2,066	9,608	1,569
	MS	5,688	43,233	1,903	1,751	7,719	1,351
	NC	599	4,547	193	178	690	142
	SC	1,067	8,100	343	316	1,205	253
	TN	3,624	27,555	1,217	1,120	4,974	860
	VA	972	2,775	334	307	359	483
	WV	1,528	11,586	487	448	525	362
	Total	28,207	209,972	9,911	9,118	36,275	7,413
Military Marine (2283)	VA	110	313	25	23	27	48
	Total	110	313	25	23	27	48
Locomotives (2285)	AL	3,490	26,339	592	533	1,446	1,354
	FL	1,006	9,969	247	222	605	404
	GA	2,654	26,733	664	598	1,622	1,059
	KY	2,166	21,811	542	488	1,321	867
	MS	2,302	23,267	578	520	1,429	899
	NC	1,638	16,502	410	369	1,001	654
	SC	1,160	11,690	291	261	710	462
	TN	2,626	25,627	633	570	1,439	1,041
	VA	1,186	11,882	1,529	1,375	3,641	492
	WV	1,311	13,224	329	296	808	517
	Total	19,540	187,044	5,815	5,232	14,022	7,750
Grand Total		118,739	420,228	22,823	21,170	52,931	24,881

Table 5. Change in 2002 Emissions, Final Inventory Relative to Preliminary Inventory
Original Table from September 6, 2004 Document

Source	State	CO	NO_x	PM-10	PM-2.5	SO_2	VOC
Aircraft (2275)	AL	0%	0%	-67%	-82%	0%	0%
	FL	-11%	-26%	-95%	-93%	-24%	-1%
	GA	+109%	+442%	-62%	-47%	+379%	+26%
	KY	0%	0%	-93%	-90%	0%	0%
	MS	0%	0%	-92%	-89%	0%	0%
	NC	0%	0%	-93%	-90%	0%	0%
	SC	0%	0%	-9%	+29%	0%	0%
	TN	+6%	+4%	-91%	-87%	+4%	+2%
	VA	-45%	-51%	-92%	-89%	+236%	-22%
	WV	0%	0%	-92%	-89%	0%	0%
	Total	-9%	-6%	-92%	-88%	+34%	-6%
Commercial Marine (2280)	AL	+0%	+0%	+0%	+0%	+0%	+0%
	FL	0%	0%	0%	0%	0%	0%
	GA	+0%	+0%	+0%	+0%	+0%	+0%
	KY	0%	0%	0%	0%	0%	0%
	MS	+0%	+0%	+0%	+0%	+0%	+0%
	NC	+0%	+0%	+0%	+0%	+0%	+0%
	SC	0%	0%	0%	0%	0%	0%
	TN	-12%	-12%	-12%	-12%	-14%	-12%
	VA	-19%	-19%	-64%	-64%	-89%	-19%
	WV	-27%	-27%	-27%	-27%	-27%	-27%
	Total	-4%	-4%	-9%	-9%	-10%	-5%
Military Marine (2283)	VA	-19%	-19%	-12%	-12%	-12%	-19%
	Total	-19%	-19%	-12%	-12%	-12%	-19%
Locomotives (2285)	AL	0%	0%	0%	0%	0%	0%
	FL	0%	0%	0%	0%	0%	0%
	GA	+3%	+3%	+3%	+3%	+3%	+3%
	KY	0%	0%	0%	0%	0%	0%
	MS	0%	0%	0%	0%	0%	0%
	NC	0%	0%	0%	0%	0%	0%
	SC	0%	0%	0%	0%	0%	0%
	TN	-42%	-43%	-43%	-43%	-46%	-42%
	VA	-38%	-39%	+9%	+9%	+6%	-38%
	WV	+19%	+19%	+19%	+19%	+19%	+19%
	Total	-11%	-11%	-5%	-5%	-6%	-11%
Grand Total		-8%	-7%	-77%	-71%	-7%	-7%

Table 5. Change in 2002 Emissions, Final Inventory Relative to Preliminary Inventory
Revised Table (Changes in Red Font)

Source	State	CO	NO_x	PM-10	PM-2.5	SO_2	VOC
Aircraft (2275)	AL	0%	0%	-67%	-82%	0%	0%
	FL	-11%	-26%	-95%	-93%	-24%	-1%
	GA	+109%	+442%	-62%	-47%	+379%	+25%
	KY	0%	0%	-93%	-90%	0%	0%
	MS	0%	0%	-92%	-89%	0%	0%
	NC	0%	0%	-93%	-90%	0%	0%
	SC	0%	0%	-9%	+29%	0%	0%
	TN	+6%	+4%	-91%	-87%	+4%	+2%
	VA	-45%	-51%	-92%	-89%	+236%	-22%
	WV	0%	0%	-92%	-89%	0%	0%
	Total	-9%	-6%	-92%	-88%	+34%	-6%
Commercial Marine (2280)	AL	+0%	+0%	+0%	+0%	+0%	+0%
	FL	0%	0%	0%	0%	0%	0%
	GA	+0%	+0%	+0%	+0%	+0%	+0%
	KY	0%	0%	0%	0%	0%	0%
	MS	+0%	+0%	+0%	+0%	+0%	+0%
	NC	+0%	+0%	+0%	+0%	+0%	+0%
	SC	0%	0%	0%	0%	0%	0%
	TN	-12%	-12%	-12%	-12%	-14%	-12%
	VA	-19%	-19%	-64%	-64%	-89%	-19%
	WV	-27%	-27%	-27%	-27%	-27%	-27%
	Total	-4%	-4%	-9%	-9%	-10%	-5%
Military Marine (2283)	VA	-19%	-19%	-12%	-12%	-12%	-19%
	Total	-19%	-19%	-12%	-12%	-12%	-19%
Locomotives (2285)	AL	0%	0%	0%	0%	0%	0%
	FL	0%	0%	0%	0%	0%	0%
	GA	0%	0%	0%	0%	0%	0%
	KY	0%	0%	0%	0%	0%	0%
	MS	0%	0%	0%	0%	0%	0%
	NC	0%	0%	0%	0%	0%	0%
	SC	0%	0%	0%	0%	0%	0%
	TN	-42%	-43%	-43%	-43%	-46%	-42%
	VA	-38%	-39%	+9%	+9%	+6%	-38%
	WV	+19%	+19%	+19%	+19%	+19%	+19%
	Total	-11%	-12%	-5%	-5%	-6%	-11%
Grand Total		-8%	-8%	-77%	-71%	-7%	-7%

Table 6. Georgia Records Included in the Mississippi CERR File

FIP Code	SCC	Pollutant	Emissions
13285	2275001000	CO	0.13
13285	2275001000	NOX	0
13285	2275001000	PM10-PRI	0
13285	2275001000	PM25-PRI	0
13285	2275001000	SO2	0
13285	2275001000	VOC	0
13285	2275050000	CO	1.64
13285	2275050000	NOX	0
13285	2275050000	PM10-PRI	0.03
13285	2275050000	PM25-PRI	0.02
13285	2275050000	SO2	0
13285	2275050000	VOC	0.05
13285	2285002006	CO	26.26
13285	2285002006	NOX	266.64
13285	2285002006	PM10-PRI	6.61
13285	2285002006	PM25-PRI	5.95
13285	2285002006	SO2	16.66
13285	2285002006	VOC	9.92
13287	2285002006	CO	39.6
13287	2285002006	NOX	401.99
13287	2285002006	PM10-PRI	9.97
13287	2285002006	PM25-PRI	8.97
13287	2285002006	SO2	25.13
13287	2285002006	VOC	14.96
13289	2285002006	CO	3.59
13289	2285002006	NOX	36.5
13289	2285002006	PM10-PRI	0.9
13289	2285002006	PM25-PRI	0.81
13289	2285002006	SO2	2.28
13289	2285002006	VOC	1.35
13289	2285002010	CO	1.51
13289	2285002010	NOX	14.31
13289	2285002010	PM10-PRI	0.35
13289	2285002010	PM25-PRI	0.33
13289	2285002010	SO2	0.66
13289	2285002010	VOC	0.83

additional matching criteria are required. For subsequent reference, this initial (highest resolution) matching criterion is denoted as the "CAIR-Primary" criterion.

(d) A second matching criterion is applied that utilizes a similar, but higher-level SCC (lower resolution) matching approach. For example, SCC 2275020000 (commercial aircraft) in the 2002 file, is coupled with SCC 2275000000 (all aircraft) in the CAIR file. This criterion is applied to records in the 2002 emissions file that are not matched using the "CAIR-Primary" criterion, and is also performed at the state-county-SCC-pollutant level of detail. For subsequent reference, this is denoted as the "CAIR-Secondary" criterion. At the end of this process, a number of unmatched records continue to remain, so a third level matching criterion is required.

(e) In the third matching step, the most frequently used SCC in the EPA CAIR files for each of the aircraft, locomotive, and commercial marine sectors is averaged at the state level to produce a "default" state and pollutant-specific growth and control factor for the sector. The resulting factor is used as a "default" growth factor for all unmatched county-SCC-pollutant level data in each state. In effect, state-specific growth data are applied to county level data for which an explicit match between the VISTAS 2002 and EPA CAIR files could not be developed. The default growth and control SCCs are 2275020000 (commercial aircraft) for the aircraft sector, 2280002000 (commercial marine diesel total) for the CMV sector, and 2285002000 (railroad equipment diesel total) for the locomotive sector. Matches made using this criterion are denoted as "CAIR-Tertiary" matches.

(f) According to EPA documentation, the CAIR baseline emissions include the impacts of the (then proposed) Tier 4 (T4) nonroad diesel rulemaking, which implements a low sulfur fuel requirement that affects both future CMV and locomotive emissions. However, the impacts of this rule were originally intended to be excluded from the initial VISTAS 2018 forecast, which was to include only "on-the-books" controls.[1] Therefore, a second set of EPA CAIR files that excluded the Tier 4 diesel impacts was obtained and the same matching exercise described above in steps (b) through (e) was performed using these "No T4" files. It is important to note that the matching exercise described in steps (b) through (e) cannot simply be replaced because the "No T4" files obtained from the EPA include only those SCCs specifically affected by the T4 rule (i.e., diesel CMV and locomotives). So in effect, the matching exercise is augmented (rather than replaced) with an additional three criteria analogous to those described in steps (c) through (e), and these are denoted as the "No

[1] The T4 rule was finalized subsequent to the development of the preliminary 2018 inventory in March of 2004. Given its final status, T4 impacts have now been moved into the "on the books" inventory for nonroad equipment. In addition, since there are no other proposed rules affecting the nonroad sector between now and 2018, there is no difference between the 2018 "on the books" and 2018 "on the way" inventories for the sector; so that only a single forecast inventory (for each evaluation year) is developed. Nevertheless, since the algorithms developed to produce the VISTAS forecasts were developed when there was a distinction between the "on the books" and "on the way" inventories, the distinct algorithms used to produce the two inventories have been maintained even though the conceptual distinctions have been lost. This approach is taken for two reasons. First, it allows the previously developed algorithms to be utilized without change. Second, it allows for separate treatment of the T4 emissions impacts and this is important as those impacts have changed between the proposed and final T4 rules, so that previous EPA inventories that include the proposed T4 impacts will not be accurate. Therefore, the procedural discussion continues to reflect the distinctions between non-T4 and T4 emissions, as these distinctions continue to be intrinsically important to the forecasting process.

T4-Primary," "No T4-Secondary," and "No T4-Tertiary" criteria. Because they exclude the impacts of the proposed T4 rule, matches using the "No T4" criteria supersede matches made using the basic CAIR criteria (as described in steps (c) through (e) above).

(g) The CAIR matching criteria are overridden for any record for which states have provided local growth data. At this time, this has only occurred for North Carolina forecasts, as that state has provided specific growth factors for airport emissions in four counties. Because the provided data are based on forecasted changes in landings and takeoffs at major North Carolina airports, the factors were applied only to commercial (SCC 2275020000) and air taxi (SCC 2275060000) emissions. Emissions forecasts for military and general aviation aircraft operations, as well as all aircraft operations in counties other than the four identified in the North Carolina growth factor submission, continue to utilize the growth factors developed according to steps (b) through (f) above. The locally generated growth factors applied in North Carolina are as follows:

FIP	2009 Factor	2018 Factor
37067	0.71	0.84
37081	0.97	0.89
37119	1.15	1.01
37183	0.88	0.81

Growth factor = Year Emissions/2002 Emissions.
Under CAIR approach, 2009 = 1.16 to 1.17 for all 4 counties.
Under CAIR approach, 2018 = 1.36 to 1.37 for all 4 counties.

(h) Using this approach, each state-county-SCC-pollutant is assigned a combined growth and control factor using the EPA CAIR forecast or locally provided data. The 22,838 data records for aircraft, locomotives, and CMV in the 2002 emissions file were assigned growth factors in accordance with the following breakdown:

48 records matched state-provided growth factors,
4,179 records matched using the CAIR-Primary criterion,
240 records matched using the CAIR-Secondary criterion,
7,463 records matched using the CAIR-Tertiary criterion,
720 records matched using the No T4-Primary criterion,
3,858 records matched using the No T4-Secondary criterion, and
6,330 records matched using the No T4-Tertiary criterion.

(i) Finally, the impacts of the adopted T4 rule are applied to the grown "non T4" emission estimates. The actual T4 emission standards do not affect aircraft, locomotive, or CMV directly, but associated diesel fuel sulfur requirements do affect locomotives and CMV. Lower fuel sulfur content affects both SO_2 and PM emissions. Expected fuel sulfur contents were obtained for each evaluation year from the EPA technical support document for the final T4 rule (*Final Regulatory Analysis: Control of Emissions from Nonroad Diesel Engines*, EPA420-R-04-007, May 2004). According to that material, the average diesel fuel sulfur content for locomotives and CMV is expected to be 408 ppmW in 2009 and 56 ppmW in 2018. These compare to expected non-T4 fuel sulfur levels of 2599 ppmW in 2009 and 2336 ppmW in 2018. Using presented emissions estimates for both base and T4 control scenarios, emission reduction impacts are estimated as follows:

				2009	2018
CMV SO_2	=	Non-T4 SO_2	×	0.1569	0.0241
Locomotive SO_2	=	Non-T4 SO_2	×	0.1569	0.0241
CMV PM	=	Non-T4 PM	×	0.8962	0.8762
Locomotive PM	=	Non-T4 PM	×	0.8117	0.7734

However, since the diesel fuel sulfur content assumed for the 2002 VISTAS inventory, upon which both the 2009 and 2018 inventories are based, is 2500 ppmW, a small adjustment to the emission reduction multipliers calculated from the T4 rule is appropriate since they are measured relative to modestly different sulfur contents (2599 ppmW for 2009 and 2336 ppmW for 2018). Correcting for these modest differences produces the following emission reduction impact estimates relative to forecasts based on the VISTAS 2002 inventory:

				2009	2018
CMV SO_2	=	Non-T4 SO_2	×	0.1632	0.0225
Locomotive SO_2	=	Non-T4 SO_2	×	0.1632	0.0225
CMV PM	=	Non-T4 PM	×	0.9004	0.8685
Locomotive PM	=	Non-T4 PM	×	0.8187	0.7610

These factors are applied directly to the non-T4 emission forecasts to produce the final VISTAS 2009 and 2018 emissions inventories for aircraft, locomotive, and CMV. The only exception is for Palm Beach County, Florida, where CMV emissions are reported as "all fuels" rather than separately by residual and diesel fuel components. To estimate T4 impacts in Palm Beach County, the ratio of diesel CMV emissions to total CMV emissions in the remainder of Florida was calculated and the T4 impact estimates for Palm Beach County were adjusted to reflect that ratio. The calculated diesel CMV ratios are as follows:

	SO_2	PM
2009 (1996, 2020 Growth Basis)	0.2410	0.7861
2009 (1996, 2010, 2015, and 2020 Growth Basis)	0.1279	0.7875
2018 (1996, 2020 Growth Basis)	0.2432	0.7925
2018 (1996, 2010, 2015, and 2020 Growth Basis)	0.2624	0.7918

The differences between the growth bases are discussed in detail below.

Combining these ratios with the T4 impact estimates for diesel engines, as presented above, yields the following impact adjustment factors for Palm Beach County:

2009 SO_2 (19, 20 Growth Basis)	0.7894	[0.1632×0.2410+(1-0.2410)]
2009 SO_2 (96, 10, 15, and 20 Growth Basis)	0.8930	[0.1632×0.1279+(1-0.1279)]
2018 SO_2 (96, 20 Growth Basis)	0.7623	[0.0225×0.2432+(1-0.2432)]
2018 SO_2 (96, 10, 15, and 20 Growth Basis)	0.7436	[0.0225×0.2624+(1-0.2624)]

2009 PM (19, 20 Growth Basis)	0.9217	[0.9004×0.7861+(1-0.7861)]
2009 PM (96, 10, 15, and 20 Growth Basis)	0.9216	[0.9004×0.7875+(1-0.7875)]
2018 PM (96, 20 Growth Basis)	0.8958	[0.8685×0.7925+(1-0.7925)]
2018 PM (96, 10, 15, and 20 Growth Basis)	0.8959	[0.8685×0.7918+(1-0.7918)]

The differences between the growth bases are discussed in detail below.

Utilizing this approach, emission inventory forecasts for both 2009 and 2018 were developed. As indicated in step (b) above, basic growth factors were developed using EPA CAIR inventory data for 1996, 2010, 2015, and 2020. From these data, equivalent EPA CAIR inventories for 2002 and 2009 were developed through linear interpolation of the 1996 and 2010 inventories, while an equivalent CAIR inventory for 2018 was developed through linear interpolation of the 2015 and 2020 inventories. Growth factors for 2009 and 2018 were then estimated as the ratios of the CAIR 2009 and 2018 inventories to the CAIR 2002 inventory.

During the development of the preliminary 2018 VISTAS inventory in March, this process yielded reasonable results and exhibited no particular systematic concerns. However, when the 2009 inventory was developed for this latest round of modeling, significant concerns related to SO_2 and PM were encountered. Essentially, what was revealed by this “mid-term” forecast were a series of apparent inconsistencies in the CAIR 2010 and 2015 emission inventories (as compared to the 1996 and 2020 CAIR inventories) that were masked during the construction of the “longer-term” 2018 inventories.

The best way of illustrating the apparent inconsistencies is through actual data extracted from the CAIR inventory files. Note that although a limited example is being presented, the same general issue applies throughout the CAIR files. For FIP 01001 (Autauga County, Alabama) and SCC 2285002000 (Diesel Rail), the CAIR inventories indicate the following SO_2 emission estimates:

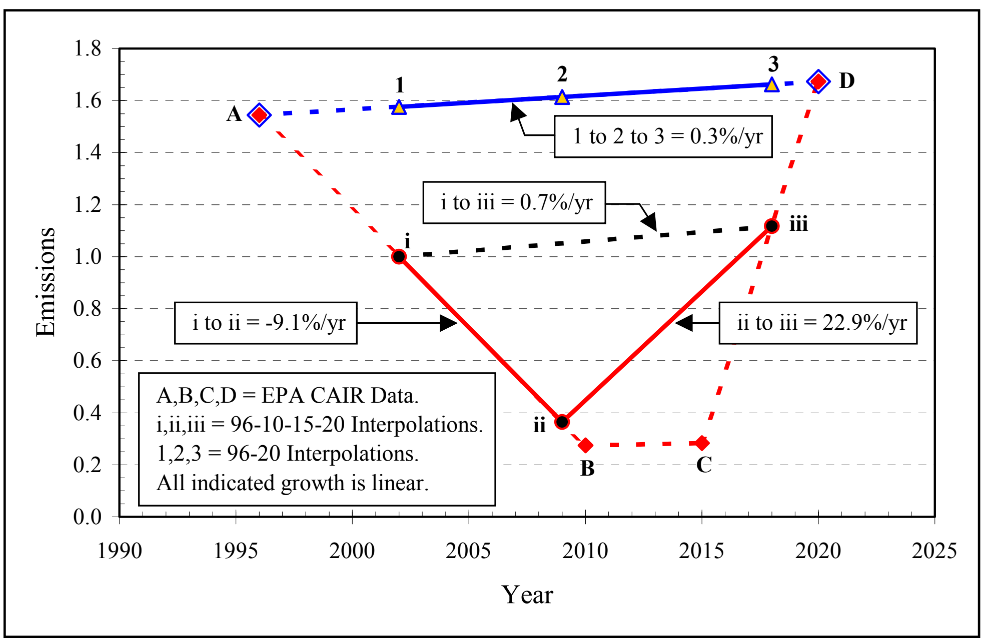
1996:	15.3445	tons
2010:	2.7271	tons
2015:	2.8178	tons
2020:	16.6232	tons

Clearly, there is a major drop in emissions between 1996 and 2010, followed by a major increase in emissions between 2015 and 2020. Several observations regarding these changes are important. First, these CAIR data are reported to exclude the T4 rule, so that the drop in emissions must be related to something other than changes in diesel fuel sulfur content. Second, if the T4 rule impacts were “accidentally” included in the estimates, there should be a 90 percent drop in diesel sulfur between 2010 and 2015; so such inclusion is unlikely. Third, the rate of growth between 2015 and 2020 (43 percent *per year* compound or 97 percent *per year* linear) is well beyond any reasonable expectations for rail service; and fuel sulfur content during this period is constant both with and without T4. In short, there appears to be no rational explanation for the data, yet the same basic relations are observed for thousands of CAIR inventory records.

For the most part, the issue seems to be centered on SO_2 and PM records, which are those records affected by the T4 rule. But, as noted above, there does not seem to be any pattern of consistency that would indicate that either inclusion or exclusion of T4 rule impacts is the underlying cause. Moreover, where they occur, the observed growth extremes generally affect both SO_2 and PM equally, while one would expect PM effects to be buffered if the T4 rule was the underlying cause, since changes in diesel fuel sulfur content will only affect a fraction of PM (i.e., sulfate), while directly reducing SO_2.

The data presented in Figure 1 illustrates what this means to the VISTAS forecasting process. Figure 1 depicts the same data presented above for Autauga County, Alabama, but normalized so that the interpolated 2002 emissions estimate is equal to unity. The "raw" CAIR data is depicted by the red markers labeled A, B, C, and D. Interpolated data for 2002 and 2009, based on 1996 and 2010 CAIR data, is depicted by the black markers labeled i and ii. Interpolated data for 2018, based on 2015 and 2020 CAIR data is depicted by the black marker labeled iii. The relationship between marker iii and marker i is exactly the relationship used to construct the preliminary 2018 VISTAS inventory (i.e., a linear growth rate equal to 0.7 percent per year). Thus, it is easy to see that although there is a major "dip and rise" between 2002 and 2018, it is essentially masked unless an intervening year is examined. Since no intervening year was examined for the preliminary inventory, the "dip and rise" was not noticed. However, upon the development of the 2009 inventory forecast, the issue became obvious, as the marker labeled ii readily illustrates. In effect, the 2009 inventory reflected very low negative "growth rates" for some SCCs and pollutants relative to the 2002 inventory, while the 2018 inventory reflected very high and positive growth rates for those same SCCs and pollutants. In effect, the path between 2002 and 2018 that previously looked like the dotted black line connecting markers i and iii, now looks like the solid red line connecting markers i, ii, and iii. For reference purposes, this path is

Figure 1. Impacts of the Apparent CAIR Inventory Discrepancy



hereafter referred to as the 1996, 2010, 2015, and 2020 growth basis, since all interpolated data is based on CAIR data for those four years.

In light of the apparent discrepancies inherent in the 1996, 2010, 2015, and 2020 growth basis data and the inconsistencies its use would impart into the 2009 and 2018 VISTAS inventories, a secondary forecasting method was developed. This second method relies on the apparent consistency between the 1996 and 2020 non-T4 CAIR inventories, interpolating equivalent 2002, 2009, and 2018 inventories solely from these two inventories. In effect, the CAIR inventories for 2010 and 2015 are ignored. In Figure 1, this secondary approach is depicted by the data points that lie along the blue lines connecting markers A and D. Markers A and D represent the 1996 and 2020 CAIR inventories, and the markers labeled 1, 2, and 3 represent the interpolated 2002, 2009, and 2018 CAIR equivalent inventories. The growth rate between 2009 and 2002 is then equal to the ratio of the 2009 and 2002 CAIR inventories, while that between 2018 and 2002 is equal to the ratio of the 2018 and 2002 CAIR inventories. For the example data, the resulting linear growth estimate is 0.3 percent per year. For reference purposes, this path is hereafter referred to as the 1996-2020 growth basis, since all interpolated data is based on CAIR data for only those two years.

It is perhaps worth noting that the only elements of Figure 1 that have any bearing on the VISTAS inventories are the growth rates. The absolute CAIR data are of importance only in determining those rates, as all VISTAS inventories are developed on the basis of the VISTAS 2002 inventory, not any of the CAIR inventories. So referring to Figure 1, the two growth options can be summarized as follows:

1996, 2010, 2015, 2020 Growth Basis:	-9.1	% per year (linear) between 2002 and 2009
1996-2020 Growth Basis:	+0.3	% per year (linear) between 2002 and 2009
1996, 2010, 2015, 2020 Growth Basis:	+22.9	% per year (linear) between 2009 and 2018
1996-2020 Growth Basis:	+0.3	% per year (linear) between 2009 and 2018
1996, 2010, 2015, 2020 Growth Basis:	+0.7	% per year (linear) between 2002 and 2018
1996-2020 Growth Basis:	+0.3	% per year (linear) between 2002 and 2018

Of course, these specific rates are applicable only to the example case (i.e., diesel rail SO_2 in Autauga County, Alabama), but there are thousands of additional CAIR records that are virtually identical from a growth viewpoint.

Forecast inventories for aircraft, locomotives, and CMV have been developed for 2009 and 2018 using both growth methods. Tables 7 through 10 present a summary of each inventory, while Tables 11 through 14 present the associated change in emissions for each forecast inventory relative to the final 2002 VISTAS inventory. As might be expected given the preceding discussion, the primary difference between the growth methods is reflected in the 2009 inventories for SO_2 and PM. The larger reduction in CMV SO_2 emissions in 2009 and 2018 (relative to 2002) for Virginia and West Virginia under either growth method is also notable relative to the other VISTAS states, but this has been checked and is attributable to a high diesel contribution to total CMV SO_2 in the 2002 inventories for these two states.

Figures 2 through 13 graphically depict the relationships between the various inventories and inventory methods. There are two figures for each pollutant, the first of which presents a comparison of total VISTAS region emission estimates for aircraft, locomotives, and CMV, and the second of which presents total VISTAS region emission estimates for locomotives only. This two figure approach is intended to provide a more robust illustration of the differences between the various inventories, as some of the differences are less distinct when viewed through overall aggregate emissions totals. All of the figures include the following emissions estimates:

- The final 2002 VISTAS emissions inventory, including the minor revisions to remove duplicate Georgia records as described above (labeled as “2002”),
- The “first cut” 2002 VISTAS emissions inventory estimates as published in February 2004 (labeled as “2002 Prelim”),
- The final 2009 VISTAS emissions inventory as developed using growth rates derived from 1996, 2010, 2015, and 2020 EPA CAIR data (labeled as “2009 (4 yr)”),
- The final 2009 VISTAS emissions inventory as developed using growth rates derived from 1996 and 2020 EPA CAIR data (labeled as “2009 (2 yr)”),
- The final 2018 VISTAS emissions inventory as developed using growth rates derived from 1996, 2010, 2015, and 2020 EPA CAIR data (labeled as “2018 (4 yr)”),
- The final 2018 VISTAS emissions inventory as developed using growth rates derived from 1996 and 2020 EPA CAIR data (labeled as “2018 (2 yr)”), and
- The “first cut” 2018 VISTAS emissions inventory estimates as developed in the spring of 2004 using growth rates derived from 1996, 2010, 2015, and 2020 EPA CAIR data (labeled as “2018 Prelim”).

All 12 figures generally illustrate a reduction in emissions estimates between the 2002 emission estimates published in February 2004 and the final 2002 emission estimates. This reduction generally results from emission updates reflected in state CERR submittals, although the major differences in aggregate PM emission estimates are driven to a greater extent by modifications in the methodology used to estimate aircraft PM, as described in the September 6, 2004 documentation of the 2002 inventory.

As illustrated in the figures for CO, NO_x, and VOC, there are generally only marginal differences between the 2009 and 2018 emissions inventory estimates developed using the 1996, 2010, 2015, and 2020 EPA CAIR growth method and the 1996-2020 EPA CAIR growth method. However, differences between the 2009 emissions estimates based on the two methods are quite pronounced for PM and SO_2 (differences in 2018 emissions are modest for these pollutants as well). As illustrated in Figures 7, 9, and 11, estimates of 2009 locomotive emissions differ by approximately a factor of three between the two methods. Figures 6, 8, and 10 show that this difference is reduced when aggregate emission estimates are considered, but differences of 10-60 percent continue to be evident.

Table 7. 2009 Aircraft, Locomotive, and Non-Recreational Marine Emissions (annual tons) -- Based on Growth Using 1996, 2010, 2015, and 2020 EPA Inventories

Source	State	CO	NO_x	PM-10	PM-2.5	SO_2	VOC
Aircraft (2275)	AL	4,303	203	279	104	19	222
	FL	29,930	10,361	2,828	2,772	932	4,270
	GA	7,849	6,262	1,720	1,686	525	523
	KY	2,709	764	209	204	73	293
	MS	1,849	163	52	51	16	111
	NC	6,654	1,602	435	427	153	647
	SC	7,798	567	451	442	99	1,006
	TN	6,984	3,090	827	811	268	1,007
	VA	11,397	3,113	1,244	1,219	911	2,940
	WV	1,267	91	29	28	9	72
	Total	80,740	26,215	8,075	7,743	3,004	11,092
Commercial Marine (2280)	AL	1,281	9,241	879	808	2,364	772
	FL	6,242	44,929	1,852	1,704	5,298	1,474
	GA	1,098	7,894	319	293	942	257
	KY	7,095	50,422	2,179	2,004	3,435	1,658
	MS	6,081	43,358	1,838	1,691	3,587	1,422
	NC	634	4,558	185	170	540	149
	SC	1,134	8,121	329	303	828	265
	TN	3,891	27,640	1,179	1,085	1,927	909
	VA	1,043	2,783	314	289	25	509
	WV	1,640	11,622	459	423	37	383
	Total	30,141	210,566	9,533	8,770	18,983	7,797
Military Marine (2283)	VA	118	314	23	21	2	50
	Total	118	314	23	21	2	50
Locomotives (2285)	AL	3,753	23,436	160	144	86	1,329
	FL	1,082	8,870	67	60	36	396
	GA	2,846	24,320	180	162	97	1,040
	KY	2,329	19,523	161	145	79	851
	MS	2,476	20,702	156	141	85	882
	NC	1,761	14,683	111	100	60	642
	SC	1,247	10,402	79	71	42	454
	TN	2,824	23,868	171	154	86	1,022
	VA	1,269	11,109	413	372	217	484
	WV	1,408	12,142	89	80	48	508
	Total	20,995	169,055	1,586	1,427	836	7,610
Grand Total		131,995	406,151	19,217	17,962	22,825	26,548

Table 8. 2009 Aircraft, Locomotive, and Non-Recreational Marine Emissions (annual tons) -- Based on Growth Using 1996 and 2020 EPA Inventories

Source	State	CO	NO_x	PM-10	PM-2.5	SO_2	VOC
Aircraft (2275)	AL	4,178	202	278	102	19	217
	FL	29,258	10,316	2,812	2,756	928	4,235
	GA	7,635	6,233	1,712	1,678	523	512
	KY	3,075	762	207	203	73	304
	MS	1,765	162	51	50	16	108
	NC	6,551	1,601	436	427	153	644
	SC	7,372	559	446	437	98	975
	TN	8,020	3,096	824	807	268	1,050
	VA	10,994	3,094	1,239	1,214	907	2,892
	WV	1,312	91	28	28	9	74
	Total	80,159	26,116	8,033	7,704	2,993	11,011
Commercial Marine (2280)	AL	1,280	8,888	872	802	2,753	768
	FL	6,236	43,198	1,838	1,691	5,864	1,467
	GA	1,097	7,599	317	291	974	256
	KY	7,087	48,039	2,158	1,985	8,350	1,649
	MS	6,074	41,437	1,821	1,676	6,587	1,415
	NC	634	4,386	184	169	584	148
	SC	1,133	7,796	326	300	1,012	264
	TN	3,887	26,333	1,168	1,074	4,512	904
	VA	1,042	2,662	312	286	61	506
	WV	1,638	11,073	455	419	89	381
	Total	30,109	201,412	9,450	8,693	30,786	7,759
Military Marine (2283)	VA	118	299	23	21	5	50
	Total	118	299	23	21	5	50
Locomotives (2285)	AL	3,648	23,529	452	406	242	1,279
	FL	1,052	8,905	189	170	101	382
	GA	2,769	24,398	507	456	271	1,003
	KY	2,264	19,597	415	374	221	819
	MS	2,406	20,785	441	397	239	849
	NC	1,712	14,741	313	282	167	618
	SC	1,213	10,443	222	200	119	437
	TN	2,745	23,924	483	435	240	984
	VA	1,236	11,134	1,167	1,050	608	467
	WV	1,369	12,177	251	226	135	489
	Total	20,412	169,635	4,440	3,995	2,343	7,328
Grand Total		130,798	397,462	21,946	20,413	36,126	26,148

Table 9. 2018 Aircraft, Locomotive, and Non-Recreational Marine Emissions (annual tons) -- Based on Growth Using 1996, 2010, 2015, and 2020 EPA Inventories

Source	State	CO	NO_x	PM-10	PM-2.5	SO_2	VOC
Aircraft (2275)	AL	4,578	235	342	121	23	241
	FL	33,610	12,107	3,298	3,232	1,089	4,946
	GA	8,745	7,315	2,009	1,969	614	592
	KY	3,899	897	243	238	86	366
	MS	1,919	190	59	58	18	120
	NC	6,641	1,453	400	393	139	612
	SC	8,134	611	489	480	111	1,094
	TN	9,828	3,520	936	918	309	1,219
	VA	12,246	3,515	1,365	1,338	1,060	3,318
	WV	1,511	106	33	33	10	86
	Total	91,111	29,947	9,176	8,779	3,458	12,594
Commercial Marine (2280)	AL	1,387	8,338	876	806	2,760	807
	FL	6,680	40,500	1,846	1,698	6,340	1,539
	GA	1,173	7,141	317	292	977	268
	KY	7,698	44,324	2,188	2,013	8,896	1,747
	MS	6,567	38,443	1,841	1,694	6,855	1,494
	NC	678	4,118	184	169	603	155
	SC	1,216	7,290	328	302	1,052	277
	TN	4,222	24,297	1,184	1,089	5,306	958
	VA	1,132	2,474	313	287	10	535
	WV	1,780	10,216	457	420	14	403
	Total	32,533	187,141	9,534	8,770	32,811	8,183
Military Marine (2283)	VA	128	276	23	21	1	53
	Total	128	276	23	21	1	53
Locomotives (2285)	AL	3,790	19,938	373	335	36	1,166
	FL	1,093	7,546	156	140	15	348
	GA	2,873	21,413	418	376	41	920
	KY	2,352	16,768	345	310	33	747
	MS	2,500	17,612	364	327	36	774
	NC	1,779	12,491	258	232	25	563
	SC	1,260	8,849	183	165	18	398
	TN	2,852	21,748	399	359	36	897
	VA	1,281	10,179	963	866	92	430
	WV	1,422	10,839	207	186	20	447
	Total	21,203	147,383	3,665	3,298	352	6,691
Grand Total		144,975	364,748	22,398	20,868	36,622	27,521

Table 10. 2018 Aircraft, Locomotive, and Non-Recreational Marine Emissions (annual tons) -- Based on Growth Using 1996 and 2020 EPA Inventories

Source	State	CO	NO_x	PM-10	PM-2.5	SO_2	VOC
Aircraft (2275)	AL	4,681	236	345	122	23	245
	FL	34,178	12,147	3,312	3,246	1,093	4,976
	GA	8,939	7,340	2,016	1,976	616	601
	KY	3,602	898	244	239	86	357
	MS	1,986	190	60	58	18	122
	NC	6,728	1,454	400	392	139	615
	SC	8,487	616	493	484	112	1,119
	TN	9,009	3,519	939	921	309	1,187
	VA	12,578	3,528	1,370	1,342	1,063	3,358
	WV	1,484	106	33	33	10	85
	Total	91,670	30,035	9,213	8,814	3,468	12,666
Commercial Marine (2280)	AL	1,388	8,464	880	809	2,715	809
	FL	6,684	41,117	1,853	1,705	6,248	1,543
	GA	1,174	7,246	319	293	976	269
	KY	7,703	45,174	2,199	2,023	8,383	1,752
	MS	6,571	39,129	1,850	1,702	6,556	1,498
	NC	679	4,179	185	170	596	155
	SC	1,217	7,406	329	303	1,027	278
	TN	4,225	24,763	1,190	1,095	4,808	960
	VA	1,133	2,517	314	289	9	537
	WV	1,781	10,412	459	422	13	404
	Total	32,554	190,407	9,578	8,811	31,330	8,205
Military Marine (2283)	VA	128	282	23	21	1	53
	Total	128	282	23	21	1	53
Locomotives (2285)	AL	3,850	19,917	381	343	34	1,183
	FL	1,110	7,538	159	143	14	353
	GA	2,917	21,395	427	385	38	932
	KY	2,389	16,751	352	317	31	757
	MS	2,540	17,594	372	335	34	785
	NC	1,807	12,478	264	237	24	571
	SC	1,280	8,840	187	168	17	404
	TN	2,897	21,735	407	367	34	910
	VA	1,300	10,173	983	885	86	436
	WV	1,444	10,831	212	190	19	453
	Total	21,534	147,252	3,744	3,368	333	6,785
Grand Total		145,885	367,975	22,557	21,015	35,132	27,709

Table 11. Change in 2009 Emissions (Based on Growth Using 1996, 2010, 2015 and 2020 EPA Inventories) from Revised Final 2002 Emissions

Source	State	CO	NO_x	PM-10	PM-2.5	SO_2	VOC
Aircraft (2275)	AL	+14%	+16%	+24%	+19%	+16%	+13%
	FL	+18%	+17%	+17%	+17%	+17%	+17%
	GA	+19%	+17%	+17%	+17%	+17%	+18%
	KY	+2%	+16%	+17%	+17%	+17%	+12%
	MS	+16%	+16%	+17%	+17%	+17%	+15%
	NC	+9%	+3%	+4%	+4%	+4%	+6%
	SC	+20%	+10%	+10%	+10%	+12%	+17%
	TN	-4%	+12%	+13%	+13%	+14%	+7%
	VA	+17%	+13%	+9%	+9%	+16%	+16%
	WV	+8%	+16%	+16%	+16%	+16%	+10%
	Total	+14%	+14%	+14%	+14%	+15%	+15%
Commercial Marine (2280)	AL	+7%	0%	-4%	-4%	-29%	+5%
	FL	+6%	0%	-4%	-4%	-21%	+5%
	GA	+6%	0%	-4%	-4%	-20%	+4%
	KY	+7%	0%	-3%	-3%	-64%	+6%
	MS	+7%	0%	-3%	-3%	-54%	+5%
	NC	+6%	0%	-4%	-4%	-22%	+4%
	SC	+6%	0%	-4%	-4%	-31%	+5%
	TN	+7%	0%	-3%	-3%	-61%	+6%
	VA	+7%	0%	-6%	-6%	-93%	+5%
	WV	+7%	0%	-6%	-6%	-93%	+6%
	Total	+7%	0%	-4%	-4%	-48%	+5%
Military Marine (2283)	VA	+7%	0%	-6%	-6%	-93%	+6%
	Total	+7%	0%	-6%	-6%	-93%	+6%
Locomotives (2285)	AL	+8%	-11%	-73%	-73%	-94%	-2%
	FL	+8%	-11%	-73%	-73%	-94%	-2%
	GA	+7%	-9%	-73%	-73%	-94%	-2%
	KY	+8%	-10%	-70%	-70%	-94%	-2%
	MS	+8%	-11%	-73%	-73%	-94%	-2%
	NC	+8%	-11%	-73%	-73%	-94%	-2%
	SC	+8%	-11%	-73%	-73%	-94%	-2%
	TN	+8%	-7%	-73%	-73%	-94%	-2%
	VA	+7%	-6%	-73%	-73%	-94%	-2%
	WV	+7%	-8%	-73%	-73%	-94%	-2%
	Total	+7%	-10%	-73%	-73%	-94%	-2%
Grand Total		+11%	-3%	-16%	-15%	-57%	+7%

Table 12. Change in 2009 Emissions (Based on Growth Using 1996 and 2020 EPA Inventories) from Revised Final 2002 Emissions

Source	State	CO	NO_x	PM-10	PM-2.5	SO_2	VOC
Aircraft (2275)	AL	+10%	+15%	+23%	+18%	+16%	+11%
	FL	+15%	+16%	+16%	+16%	+16%	+16%
	GA	+15%	+16%	+16%	+16%	+16%	+16%
	KY	+15%	+16%	+16%	+16%	+16%	+16%
	MS	+11%	+16%	+15%	+15%	+16%	+12%
	NC	+8%	+3%	+4%	+4%	+3%	+5%
	SC	+13%	+9%	+9%	+9%	+12%	+13%
	TN	+11%	+12%	+12%	+12%	+14%	+11%
	VA	+13%	+12%	+9%	+9%	+15%	+14%
	WV	+11%	+16%	+15%	+15%	+16%	+12%
	Total	+13%	+14%	+14%	+13%	+15%	+14%
Commercial Marine (2280)	AL	+7%	-4%	-5%	-5%	-18%	+4%
	FL	+6%	-4%	-5%	-5%	-12%	+4%
	GA	+6%	-3%	-5%	-5%	-17%	+4%
	KY	+7%	-4%	-4%	-4%	-13%	+5%
	MS	+7%	-4%	-4%	-4%	-15%	+5%
	NC	+6%	-4%	-5%	-5%	-15%	+4%
	SC	+6%	-4%	-5%	-5%	-16%	+4%
	TN	+7%	-4%	-4%	-4%	-9%	+5%
	VA	+7%	-4%	-7%	-7%	-83%	+5%
	WV	+7%	-4%	-7%	-7%	-83%	+5%
	Total	+7%	-4%	-5%	-5%	-15%	+5%
Military Marine (2283)	VA	+7%	-4%	-7%	-7%	-83%	+5%
	Total	+7%	-4%	-7%	-7%	-83%	+5%
Locomotives (2285)	AL	+5%	-11%	-24%	-24%	-83%	-6%
	FL	+5%	-11%	-24%	-24%	-83%	-6%
	GA	+4%	-9%	-24%	-24%	-83%	-5%
	KY	+5%	-10%	-23%	-23%	-83%	-6%
	MS	+5%	-11%	-24%	-24%	-83%	-6%
	NC	+5%	-11%	-24%	-24%	-83%	-6%
	SC	+5%	-11%	-24%	-24%	-83%	-6%
	TN	+5%	-7%	-24%	-24%	-83%	-6%
	VA	+4%	-6%	-24%	-24%	-83%	-5%
	WV	+4%	-8%	-24%	-24%	-83%	-5%
	Total	+4%	-9%	-24%	-24%	-83%	-5%
Grand Total		+10%	-5%	-4%	-4%	-32%	+5%

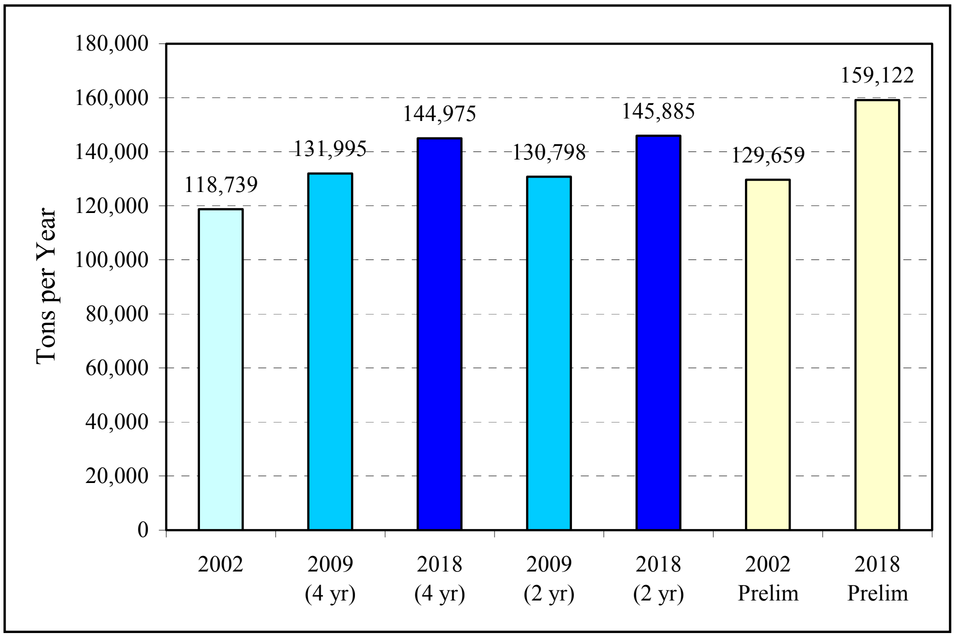
Table 13. Change in 2018 Emissions (Based on Growth Using 1996, 2010, 2015 and 2020 EPA Inventories) from Revised Final 2002 Emissions

Source	State	CO	NO_x	PM-10	PM-2.5	SO_2	VOC
Aircraft (2275)	AL	+21%	+34%	+52%	+40%	+35%	+23%
	FL	+32%	+36%	+36%	+36%	+36%	+35%
	GA	+32%	+36%	+36%	+36%	+36%	+34%
	KY	+46%	+36%	+36%	+36%	+36%	+39%
	MS	+20%	+35%	+33%	+33%	+35%	+25%
	NC	+9%	-6%	-5%	-4%	-6%	0%
	SC	+25%	+19%	+20%	+20%	+27%	+27%
	TN	+36%	+27%	+28%	+28%	+31%	+29%
	VA	+25%	+28%	+20%	+20%	+35%	+31%
	WV	+28%	+36%	+35%	+35%	+36%	+30%
	Total	+29%	+31%	+30%	+29%	+33%	+30%
Commercial Marine (2280)	AL	+16%	-10%	-4%	-4%	-17%	+10%
	FL	+13%	-10%	-5%	-5%	-5%	+9%
	GA	+13%	-9%	-5%	-5%	-17%	+9%
	KY	+17%	-12%	-3%	-3%	-7%	+11%
	MS	+15%	-11%	-3%	-3%	-11%	+11%
	NC	+13%	-9%	-5%	-5%	-13%	+9%
	SC	+14%	-10%	-4%	-4%	-13%	+10%
	TN	+17%	-12%	-3%	-3%	+7%	+11%
	VA	+17%	-11%	-6%	-6%	-97%	+11%
	WV	+17%	-12%	-6%	-6%	-97%	+11%
	Total	+15%	-11%	-4%	-4%	-10%	+10%
Military Marine (2283)	VA	+17%	-12%	-6%	-6%	-97%	+11%
	Total	+17%	-12%	-6%	-6%	-97%	+11%
Locomotives (2285)	AL	+9%	-24%	-37%	-37%	-97%	-14%
	FL	+9%	-24%	-37%	-37%	-97%	-14%
	GA	+8%	-20%	-37%	-37%	-97%	-13%
	KY	+9%	-23%	-36%	-36%	-97%	-14%
	MS	+9%	-24%	-37%	-37%	-97%	-14%
	NC	+9%	-24%	-37%	-37%	-97%	-14%
	SC	+9%	-24%	-37%	-37%	-97%	-14%
	TN	+9%	-15%	-37%	-37%	-97%	-14%
	VA	+8%	-14%	-37%	-37%	-97%	-13%
	WV	+8%	-18%	-37%	-37%	-97%	-14%
	Total	+9%	-21%	-37%	-37%	-97%	-14%
Grand Total		+22%	-13%	-2%	-1%	-31%	+11%

Table 14. Change in 2018 Emissions (Based on Growth Using 1996 and 2020 EPA Inventories) from Revised Final 2002 Emissions

Source	State	CO	NO_x	PM-10	PM-2.5	SO_2	VOC
Aircraft (2275)	AL	+24%	+35%	+53%	+41%	+36%	+25%
	FL	+34%	+37%	+37%	+37%	+37%	+36%
	GA	+35%	+37%	+37%	+37%	+37%	+36%
	KY	+35%	+37%	+37%	+37%	+37%	+36%
	MS	+25%	+36%	+35%	+35%	+36%	+27%
	NC	+10%	-6%	-5%	-5%	-6%	0%
	SC	+30%	+20%	+21%	+21%	+27%	+30%
	TN	+24%	+27%	+28%	+28%	+31%	+26%
	VA	+29%	+28%	+20%	+20%	+35%	+33%
	WV	+26%	+36%	+35%	+35%	+36%	+28%
	Total	+29%	+31%	+30%	+30%	+33%	+31%
Commercial Marine (2280)	AL	+16%	-8%	-4%	-4%	-19%	+10%
	FL	+14%	-8%	-4%	-4%	-7%	+9%
	GA	+13%	-8%	-5%	-5%	-17%	+9%
	KY	+17%	-10%	-2%	-2%	-13%	+12%
	MS	+16%	-9%	-3%	-3%	-15%	+11%
	NC	+13%	-8%	-4%	-4%	-14%	+9%
	SC	+14%	-9%	-4%	-4%	-15%	+10%
	TN	+17%	-10%	-2%	-2%	-3%	+12%
	VA	+17%	-9%	-6%	-6%	-98%	+11%
	WV	+17%	-10%	-6%	-6%	-98%	+12%
	Total	+15%	-9%	-3%	-3%	-14%	+11%
Military Marine (2283)	VA	+17%	-10%	-6%	-6%	-98%	+12%
	Total	+17%	-10%	-6%	-6%	-98%	+12%
Locomotives (2285)	AL	+10%	-24%	-36%	-36%	-98%	-13%
	FL	+10%	-24%	-36%	-36%	-98%	-13%
	GA	+10%	-20%	-36%	-36%	-98%	-12%
	KY	+10%	-23%	-35%	-35%	-98%	-13%
	MS	+10%	-24%	-36%	-36%	-98%	-13%
	NC	+10%	-24%	-36%	-36%	-98%	-13%
	SC	+10%	-24%	-36%	-36%	-98%	-13%
	TN	+10%	-15%	-36%	-36%	-98%	-13%
	VA	+10%	-14%	-36%	-36%	-98%	-11%
	WV	+10%	-18%	-36%	-36%	-98%	-12%
	Total	+10%	-21%	-36%	-36%	-98%	-12%
Grand Total		+23%	-12%	-1%	-1%	-34%	+11%

Figure 2. Total Aircraft, Locomotive, and CMV CO Emissions



"4 yr" indicates forecasts based on growth factors calculated from 1996, 2010, 2015, and 2020 EPA inventories. "2 yr" indicates forecasts based on growth factors calculated from 1996 and 2020 EPA inventories. "Prelim" indicates preliminary emissions estimates from earlier work.

Figure 3. Locomotive CO Emissions

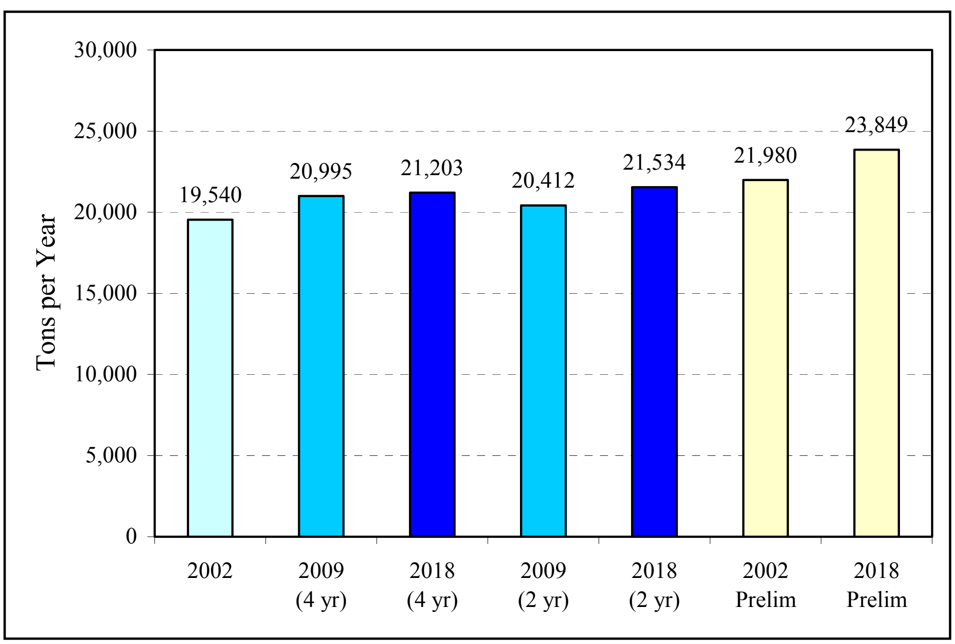
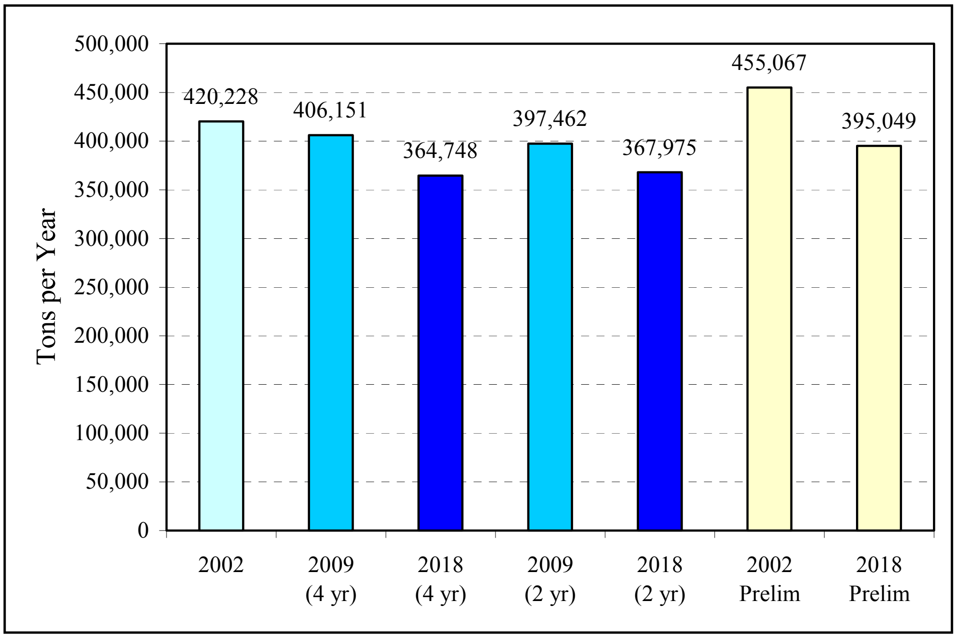


Figure 4. Total Aircraft, Locomotive, and CMV NO_x Emissions



"4 yr" indicates forecasts based on growth factors calculated from 1996, 2010, 2015, and 2020 EPA inventories. "2 yr" indicates forecasts based on growth factors calculated from 1996 and 2020 EPA inventories. "Prelim" indicates preliminary emissions estimates from earlier work.

Figure 5. Locomotive NO_x Emissions

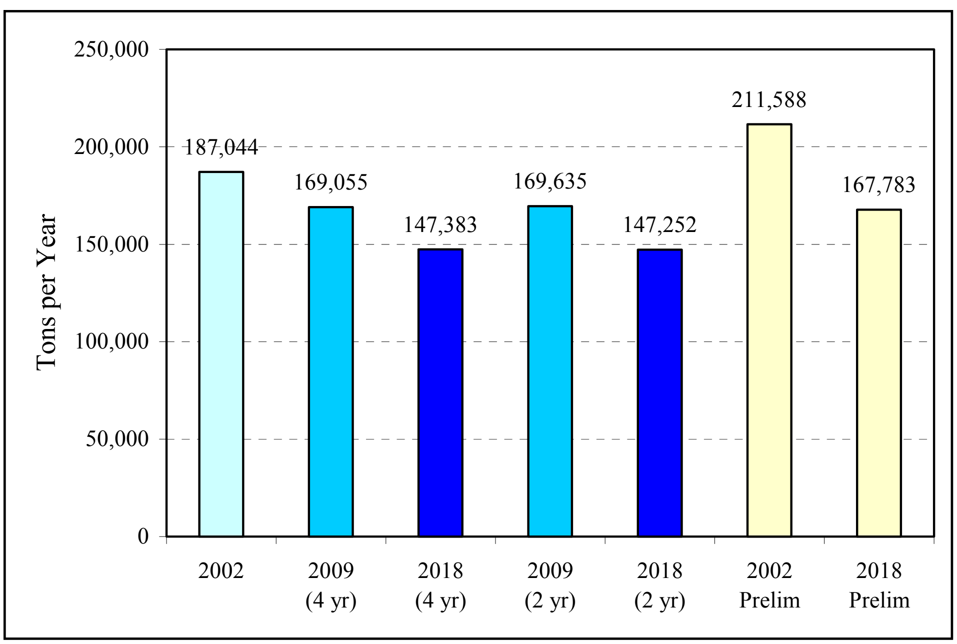
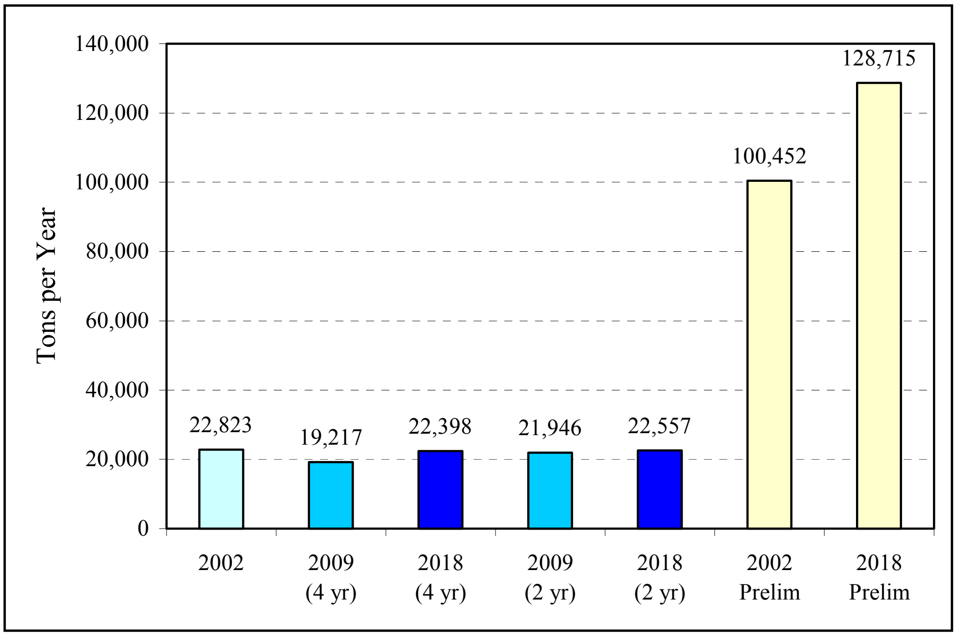


Figure 6. Total Aircraft, Locomotive, and CMV PM-10 Emissions



"4 yr" indicates forecasts based on growth factors calculated from 1996, 2010, 2015, and 2020 EPA inventories. "2 yr" indicates forecasts based on growth factors calculated from 1996 and 2020 EPA inventories. "Prelim" indicates preliminary emissions estimates from earlier work.

Figure 7. Locomotive PM-10 Emissions

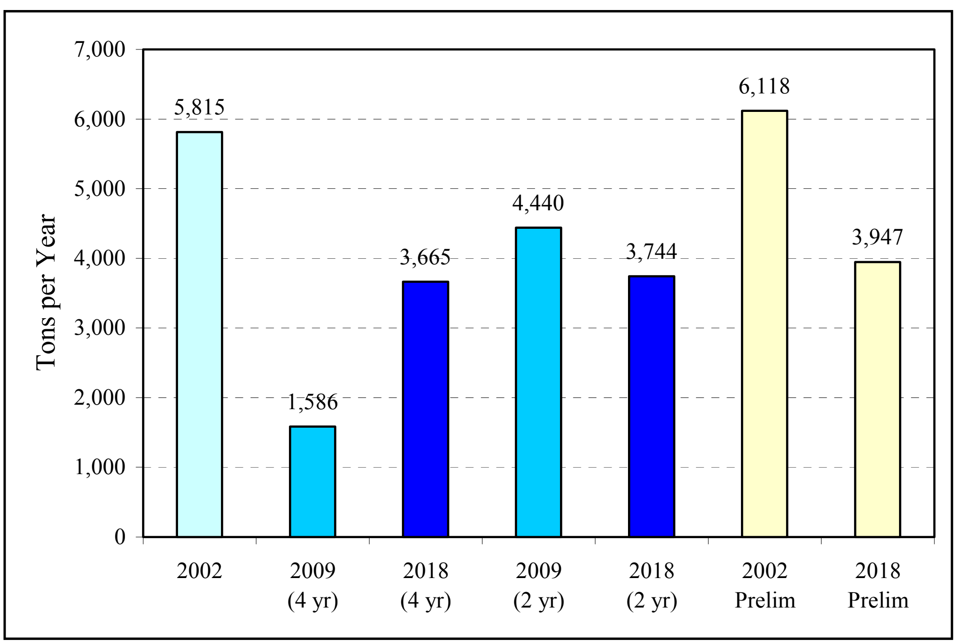
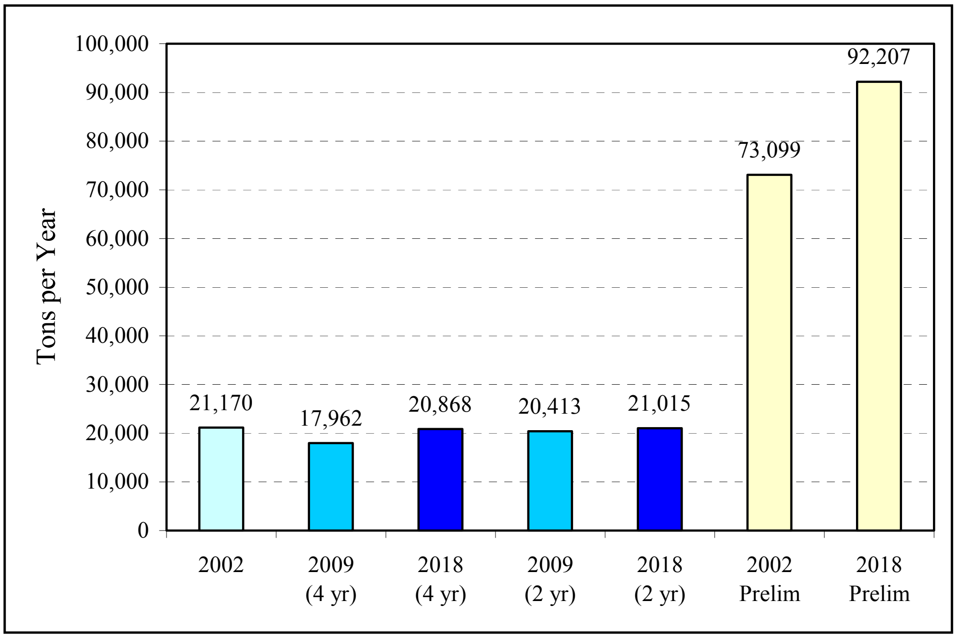


Figure 8. Total Aircraft, Locomotive, and CMV PM-2.5 Emissions



"4 yr" indicates forecasts based on growth factors calculated from 1996, 2010, 2015, and 2020 EPA inventories. "2 yr" indicates forecasts based on growth factors calculated from 1996 and 2020 EPA inventories. "Prelim" indicates preliminary emissions estimates from earlier work.

Figure 9. Locomotive PM-2.5 Emissions

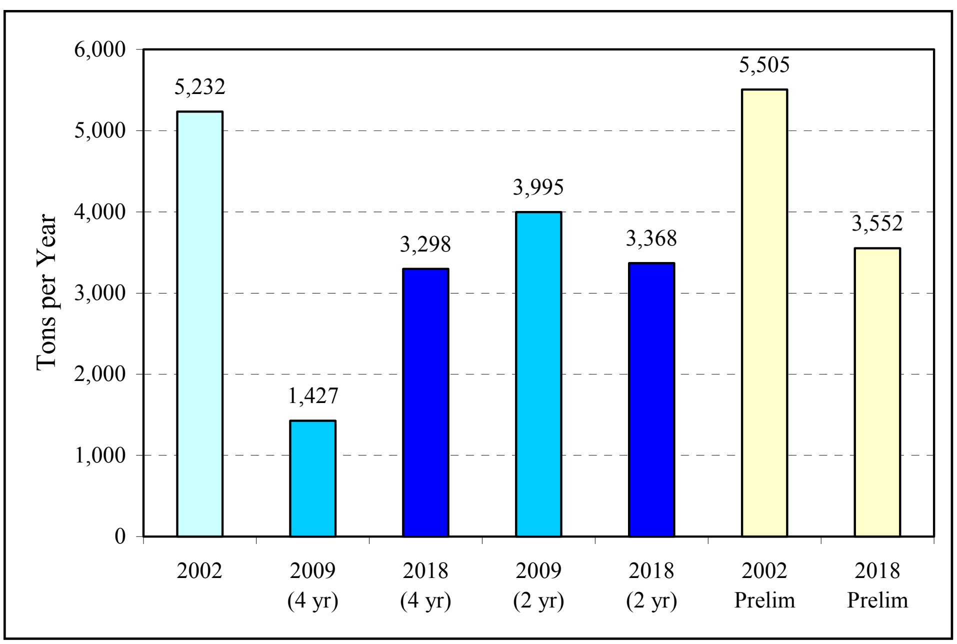
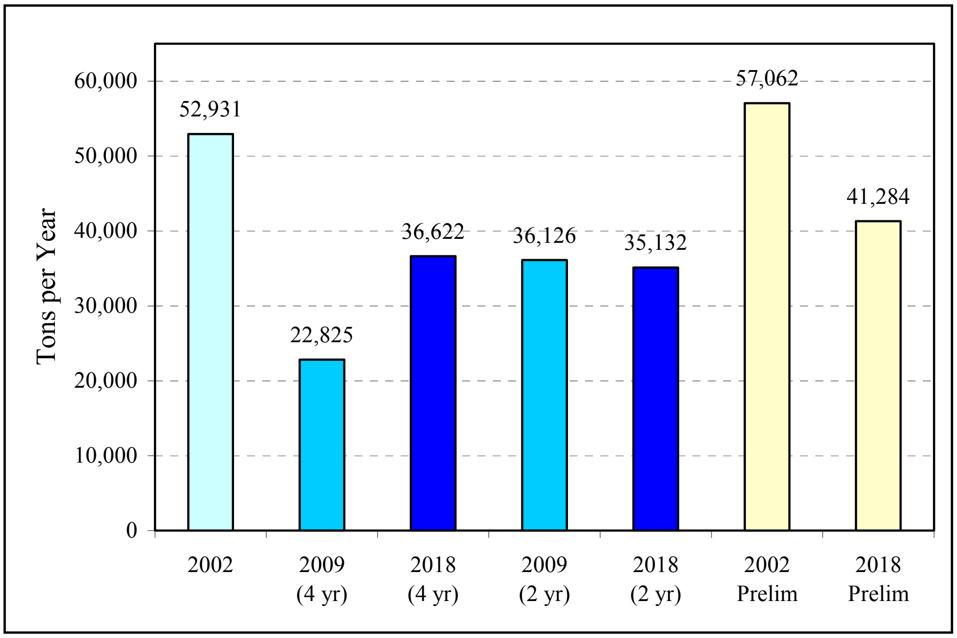


Figure 10. Total Aircraft, Locomotive, and CMV SO_2 Emissions



"4 yr" indicates forecasts based on growth factors calculated from 1996, 2010, 2015, and 2020 EPA inventories. "2 yr" indicates forecasts based on growth factors calculated from 1996 and 2020 EPA inventories. "Prelim" indicates preliminary emissions estimates from earlier work.

Figure 11. Locomotive SO_2 Emissions

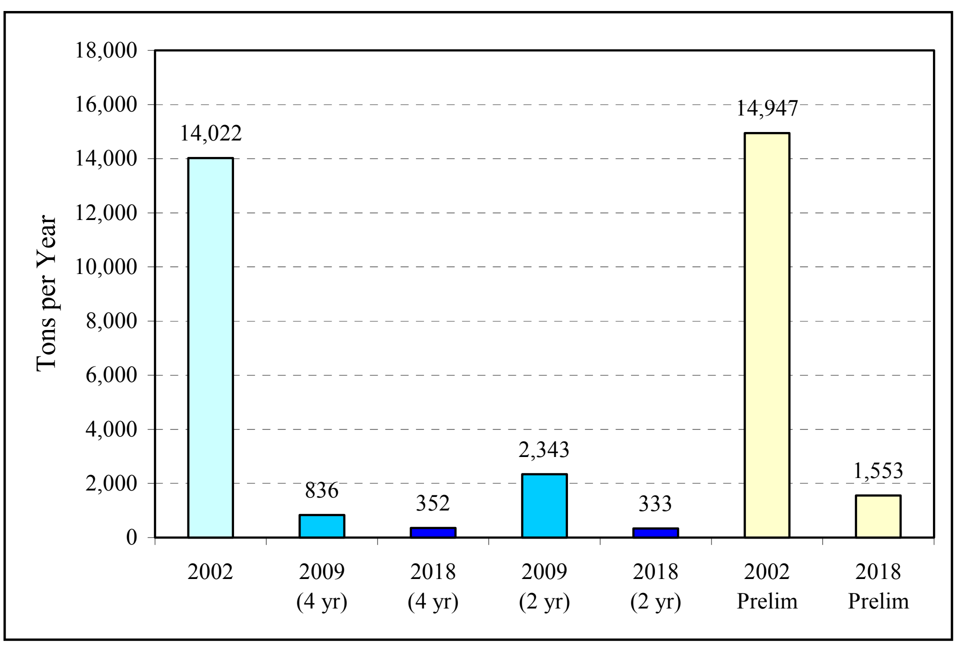
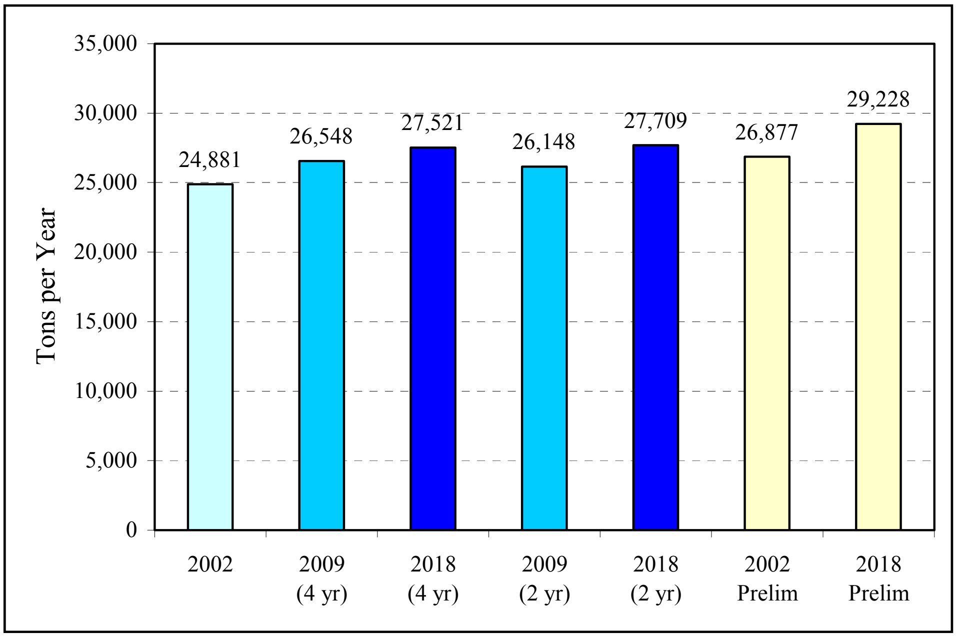


Figure 12. Total Aircraft, Locomotive, and CMV VOC Emissions



"4 yr" indicates forecasts based on growth factors calculated from 1996, 2010, 2015, and 2020 EPA inventories. "2 yr" indicates forecasts based on growth factors calculated from 1996 and 2020 EPA inventories. "Prelim" indicates preliminary emissions estimates from earlier work.

Figure 13. Locomotive VOC Emissions