Atmospheric Dispersion Modeling Analysis to Support the Dover Township Childhood Cancer Epidemiologic Study

Technical Report CCL-TR01-02

by

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Acknowledgements

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1 INTRODUCTION

The New Jersey Department of Health and Senior Services (NJDHSS) and the Agency for Toxic Substances and Disease Registry (ATSDR) have undertaken an epidemiologic study of childhood leukemia and nervous system cancers that occurred during the period 1979 through 1996 in Dover Township, Ocean County, New Jersey. The above study, which began data collection in 1998, is exploring multiple possible risk factors, including environmental exposures. One of the environmental factors of community concern investigated in the study is the potential for past exposure to hazardous air pollutants emitted from commercial and industrial facilities in the Dover Township area.

To assist with the exposure assessment component of the epidemiologic study, the Environmental and Occupational Health Sciences Institute (EOHSI) has been charged with identifying the major point source emitters potentially affecting the Dover Township area (Appendix A) that should be considered in the study. In addition, EOHSI was charged with developing historic atmospheric dispersion estimates for the selected facilities and providing to NJDHSS relative concentration magnitude prediction estimates at specific residential locations from 1962 through 1996 (the study time period) for use in the epidemiologic study. The project report summarizes this effort to provide atmospheric dispersion estimates in the Dover Township area.

2 MODELING OBJECTIVES AND STUDY AREA

The objectives of this study are:

- Development of monthly atmospheric dispersion patterns using relevant meteorological data and facility ("source") characteristics.
- Estimation of the relative magnitudes of past, monthly average, ambient gaseous and particulate concentrations from 1962 to 1996 for selected receptor locations in Ocean County, New Jersey, due to airborne emissions from nearby major industrial facilities.

The rationale of this study is that these relative concentration magnitude predictions may be utilized for reconstruction of historical exposures to airborne contaminants.

2.1 Area of Study

The study area is primarily located within Ocean County, New Jersey (see Figure 1). The Ciba-Geigy plant is located approximately 5 miles west of the Atlantic Ocean, 10 miles north-northwest of the Oyster Creek Nuclear Generating Station, and 47 miles north-northeast of Atlantic City. An aerial image of the area surrounding the Ciba-Geigy facility is provided in Figure 2.

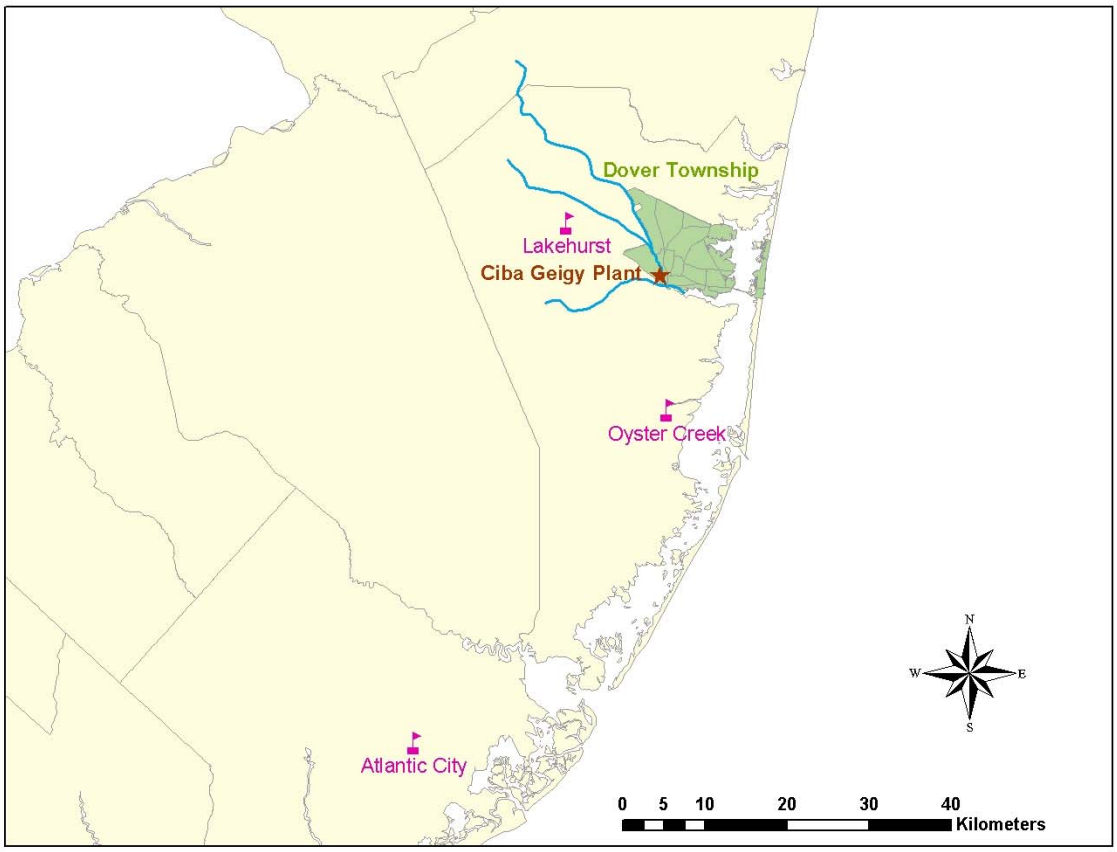


Figure 1. Location of the meteorological stations and facilities in the study area

UTM coordinates for south-west corner of the map: Easting 521502, Northing 4370265

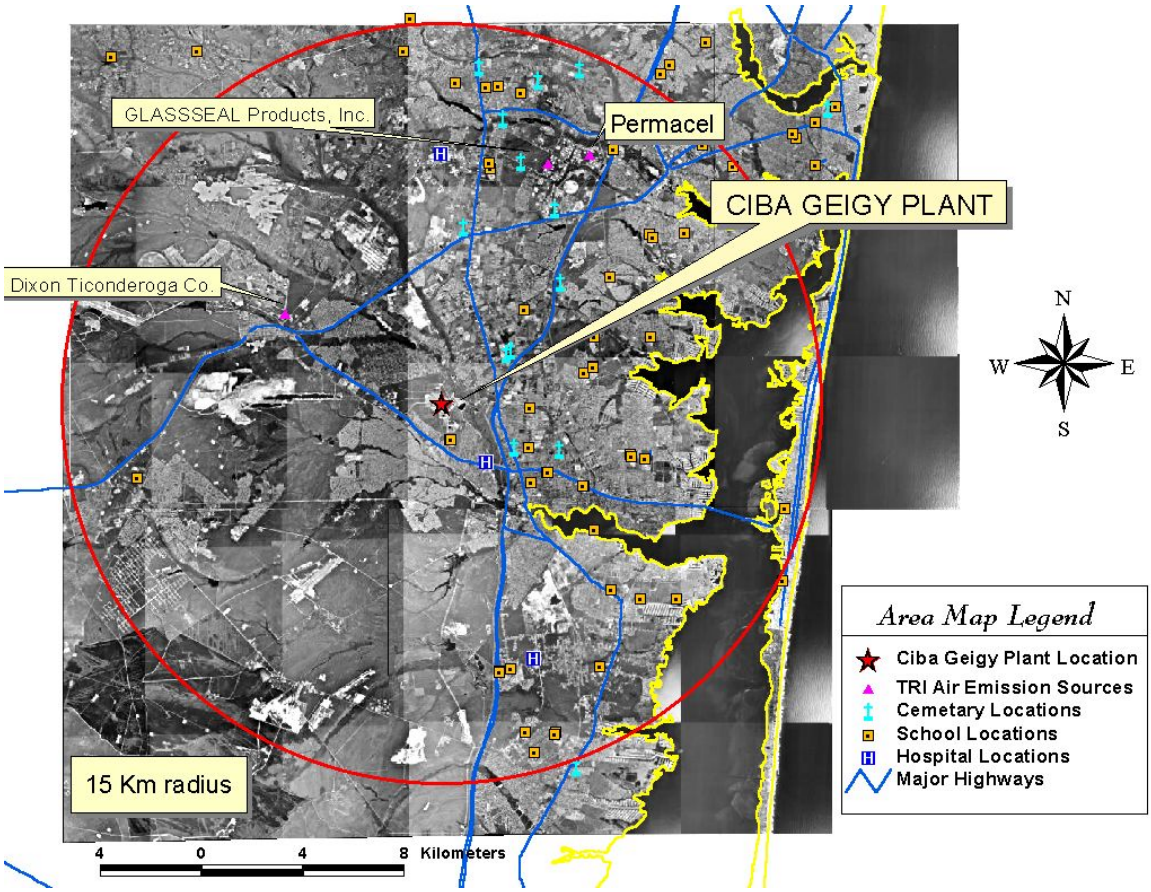


Figure 2. Aerial Image of the area surrounding the Ciba-Geigy facility

3 GENERAL APPROACH OVERVIEW

The reconstruction of past ambient, ground level, relative concentration magnitudes focuses primarily on the interpretation of meteorological factors and subsequently on reported pollutant emissions data relevant to the Dover Township area. Appropriate data have been retrieved for years 1962 through 1996.

- Meteorological data needed for the atmospheric dispersion model analysis were obtained from the National Climatic Data Center (NCDC) (Seiderman, 1999).
- Potentially major sources of pollution were identified and data compiled from records provided by the Toxics Release Inventory (TRI) (US EPA, 1998b, a) and the New Jersey Department of Environmental Protection (NJDEP) (Held, 1999). This investigation (which is summarized in Appendix A) identified one major emitter potentially affecting Dover Township: the Ciba-Geigy chemical plant located within the township. In addition, because of community concerns, emissions from the Oyster Creek Nuclear Generating Station located in Forked River, New Jersey, about 10 miles south of Dover Township, were obtained from the Nuclear Regulatory Commission (Vouglitos, 1999).
- Simulation studies for emissions relevant to the Ciba-Geigy plant were performed using a standard regulatory Gaussian dispersion model (ISCST3) with two sets of meteorological data, a) data from Atlantic City for the years 1961-1996 and, b) data from the Lakehurst station for the years 1973-1989. In this project a constant uniform level of emissions was assumed for the purpose of estimating the relative concentration magnitudes of ground level ambient pollution at the location of each study residence.
- A similar approach was used for the emissions from the Oyster Creek Nuclear Generating Station except that quarterly effluent releases reported to the Nuclear Regulatory Commission (NRC) were employed for the same source term. The modeling of past monthly ground level concentrations using Oyster Creek Nuclear Generating Station emissions focused on the years 1970-1996. Since Oyster Creek had reliable meteorological data from 1982-1998, the above data were used for 1982-1996 and Atlantic City meteorological data were used for the years 1970-1981.
- Emissions released as both gaseous and particulate matter, as well as dry deposition of particles, were considered in the dispersion modeling.

The overall modeling approach is summarized schematically in Figure 3.

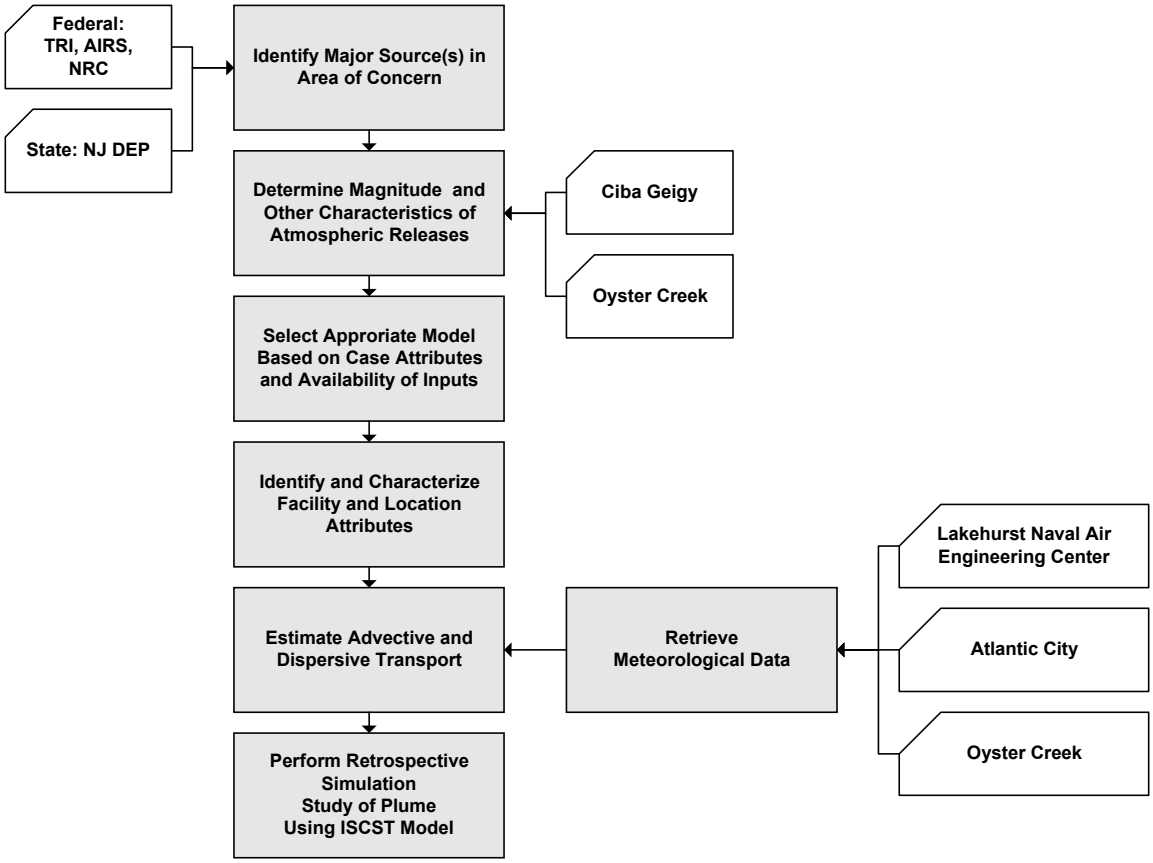


Figure 3. Overview of atmospheric modeling approach

4 DATA NEEDS FOR MODELING

The primary modeling tool for this study was the Industrial Source Complex model Short-Term version (ISCST3), which is a part of the current EPA-approved set of models for calculating atmospheric dispersion from industrial sources (US EPA, 1996; US EPA, 2000; NJDEP, 1997). The ISC family of models is especially designed to support the EPA's regulatory modeling programs. The default mode of operation includes stack-tip downwash, buoyancy-induced dispersion, final plume rise and a routine for processing calm winds. The models are capable of handling multiple sources, including point, volume and area. The models contain algorithms for modeling the effects of aerodynamic downwash due to nearby buildings, and the effects of settling and removal (through dry deposition) of large particles. The ISCST3 model, an EPA approved regulatory model, has been widely used to simulate dispersion of pollutants that are emitted from industrial work locations. The Industrial Source Complex model Long-Term version (ISCLT) has in fact been used recently in major nationwide studies for estimating the ambient levels of air toxics, such as the Cumulative Exposure Project (CEP) and the National-Scale Air Toxics Assessment (NATA) (US EPA, 1999a, 2001). The period of interest in this present study is from 1962 to 1996. The AERMOD model requires upper air rawinsonde data; however Atlantic City upper air rawinsonde data are available only from September 1980 and hence cannot cover the entire period of the present study. Evaluations of CALPUFF, based on comparisons with experimental data (described in US EPA, 1998c,d,e,f,g), have shown that CALPUFF performs very poorly for near-field dispersion calculations, typically grossly overpredicting observed concentrations. For example, in the June 1998 U.S. EPA report "A Comparison of Calpuff Modeling Results to Two Tracer Field Experiments," (US EPA, 1998d) CALPUFF is reported to overpredict monitor-recorded maximum (non-reactive species) concentrations, at distances of up to 100 km from the source, by at least a factor of 2 when standard ("Pasquill-Gifford") dispersion parameterizations were used (and almost by a factor of 2 when other parameterizations were tried). Since a significant component of the impact is calculated for relatively near-field conditions, this would render the applicability of CALPUFF to be problematic.

The ISCST3 model and relevant documentation are available on EPA's website (http://www.epa.gov/ttn/scram).

4.1 Model Inputs

The required model inputs for the ISCST3 model include both meteorological and emissions data; temporally variable quantities are typically required on an hourly basis (see Figure 4).

4.1.1 Meteorological Inputs

The ISCST3 model requires the following meteorological parameters on an hourly basis:

- Dry bulb temperature
- Ceiling height
- Total and opaque cloud cover
- Wind direction and speed

In order for the ISCST3 model to calculate the atmospheric dispersion of a pollutant it requires these meteorological variables to be pre-processed. PCRAMMET (US EPA, 1999b) is the meteorological preprocessor (available from EPA) that performs this task. The input parameters for PCRAMMET are listed and discussed in Appendix B. The specific values used in the period of concern are also presented there.

4.1.2 Emissions Inputs

The model inputs for the emissions are:

- Source location
- Stack height and diameter
- Stack emission exit velocity
- Emissions temperature
- Rate of pollutant release per hour.

These specific needs for both meteorological and emissions input data are also summarized in Figure 4. The location of the three meteorological stations with respect to the Ciba-Geigy plant is presented in Figure 1.

In addition to meteorological and stack parameters, the ISCST3 model also requires the coordinates of receptors across the modeling domain corresponding to points of interest (such as households, schools, hospitals and parks) where exposures may occur. In this study the New Jersey Department of Health and Senior Services provided a list of household receptors (locations of residences) from Ocean County. (This issue is discussed in greater detail in section 5.3.)

Issues associated with the aforementioned meteorological inputs and emissions data sources are summarized in Table 1 and Table 2. These tables also illustrate limitations of the information available to this project and some of the problems inherent with its use.

Table 1. Availability of Model Inputs: Meteorology

	Station	Availability	Location
Meteorological Inputs	Atlantic City 39.45° N 74.567° W	1962-1996	Situated 47 miles southwest from Dover Township
	Lakehurst 40.02° N 74.3497° W	1973-1989	Situated 7 miles west-northwest from Dover Township
	Oyster Creek 39.81416° N 74.20638° W	1982-1996	Situated 10 miles south-southeast from Dover Township

Table 2. Availability of model inputs: emissions

	Site	Available Data	Associated Problems
Emission Sources	Ciba-Geigy 39.9867° N 74.2363° W	Production level estimates available since 1953 TRI data reported toxic releases	Stack emission estimates unreliable TRI reporting began in 1987
	Oyster Creek 39.81416° N 74.20638° W	Effluent releases of radioactive pollutants since 1970	Only irregular quarterly emissions data available

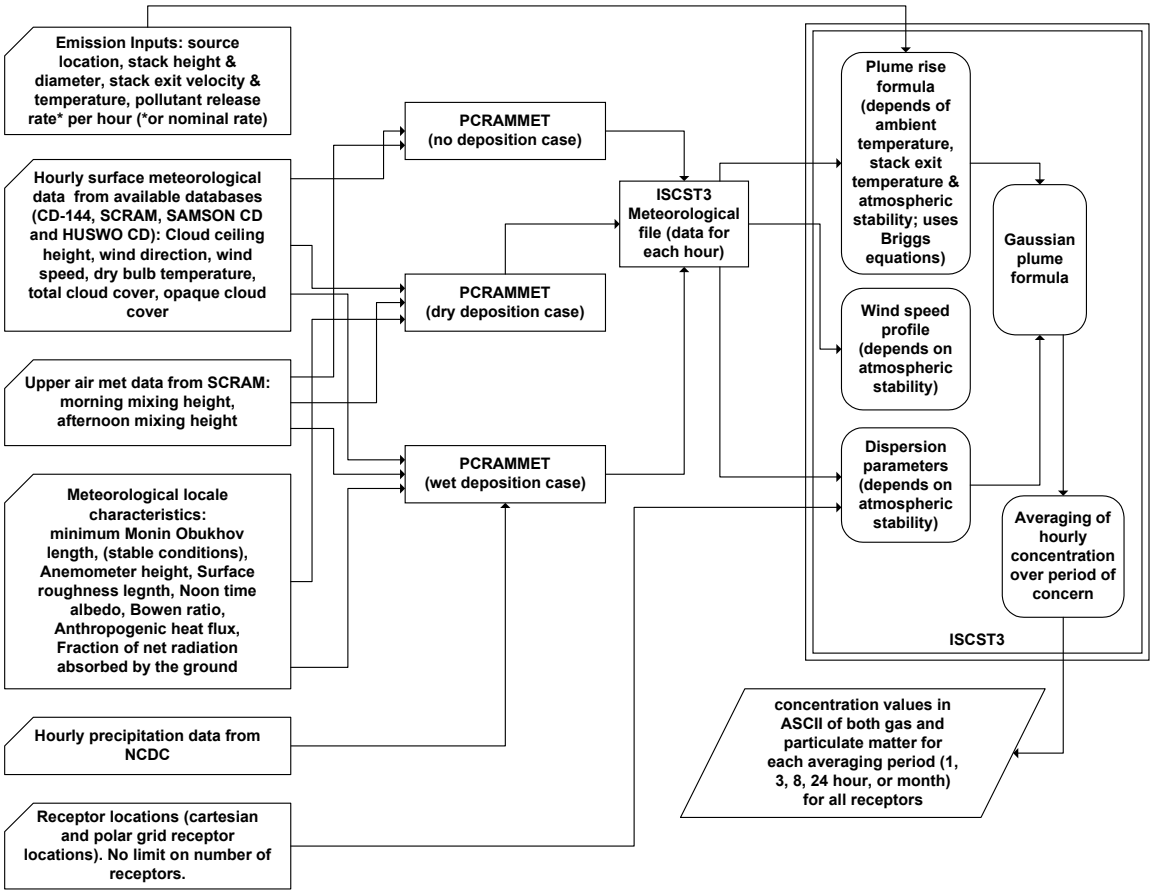


Figure 4. ISCST3 modeling framework depicting inputs, preprocessors, main model components, and attributes of outputs

5 DATA FOR MODEL INPUTS

5.1 Meteorology

The period of interest to this project is 1962 to 1996. The following descriptions of the meteorological data indicate that no complete record of meteorological data exists that represents the area of Dover Township.

- The meteorological station at Atlantic City (39.45º N, 74.567º W) was operational for the entire period and is a Class I National Weather Service (NWS) site. It therefore offers reliable and consistent data, but it is positioned approximately 47 miles to the south-southwest.
- Meteorological data for Lakehurst (40.02º N, 74.3497º W) are only available for 1973 to 1989 and are of lower quality than those for Atlantic City (due to less stringent quality assurance/quality control and more gaps in data set) yet the station is only seven miles to the west-northwest of Dover Township.
- The nuclear power generating station at Oyster Creek (39.81416º N, 74.20638º W) has reliable meteorological data available from 1982 to 1998 and is located 10 miles to the south-southeast of Dover Township. The meteorological data recorded from 1970 to 1981 were subject to numerous instrumental errors and were therefore regarded as unreliable – data from Atlantic City were used as a substitute for the modeling of Oyster Creek effluent releases for this time period since this station is similarly situated on the coastline.

A comparison of the wind roses[*] from these three locations (Figure 5, Figure 6 and Figure 7) shows the influence of a summertime sea breeze wind regime at Atlantic City, which is less evident at Lakehurst, and the dominance of westerly winds at all three locations. It is not possible to precisely determine the influence of sea breezes across the Dover Township area since the area of interest stretches from the coast to twenty miles inland.

The availability of Atlantic City and Lakehurst meteorological data has been mentioned in Table 1. In summary, Atlantic City data offer a complete 36-year record, whereas Lakehurst data were only available for 1973-1989. The Atlantic City data would represent a stable basis from which epidemiological data could be compared and analyzed; the disadvantage of these data is the station's location, 47 miles to the south-southwest of Dover Township. This brings into question its representativeness, although it is located at a similar distance inland as Dover Township and thereby one can presume it to be similarly influenced by sea breeze effects. The Lakehurst data could, conversely, be more representative of meteorological conditions in the Dover Township area, due to this station's proximity to the study area. The disadvantage posed by its short record of data is, however, of major concern and hence it was decided to restrict the analysis using Lakehurst meteorological data from the 1973-1989 period. The analysis using Atlantic City meteorological data encompassed the entire duration of the study period (1962-1996).

[*] A wind rose depicts the frequency of occurrence of winds in each of 16 direction sectors (north, north-northeast, northeast, etc.) and six wind speed classes for a given location and time period.

5.2 Emissions

The sources of emissions data investigated for this study are the following.

- The Toxic Release Inventory (TRI) (US EPA, 1998b, a)
- Permit records from the New Jersey Department of Environmental Protection (NJDEP) (Held, 1999)
- Archive records from the U.S. Environmental Protection Agency (US EPA) (Mangels, 1999)
- A RADIAN Corporation report entitled "Ambient Air Monitoring of Volatile Organic Substances at the Ciba-Geigy Toms River Chemical Plant" (Radian Corp., 1988)
- Records of production levels from Ciba-Geigy (Blando, 1999)
- Oyster Creek effluent releases obtained from the NRC (Vouglitos, 1999)

5.2.1 Emissions from Ciba-Geigy

- The TRI data (see Appendix A) contain information for the years 1987 to 1996. This time period coincides with the years the Ciba-Geigy plant was undergoing a phase-out of its operations in Dover Township and therefore cannot be considered representative of the entire study period.
- Permit records at NJDEP were searched extensively, but could not produce consistent hourly or annual emissions data needed for this study.
- The records held by U.S. EPA Region II did reveal annual emissions of various pollutants only for three individual years for each of the buildings concerned with dye and resin production.
- The report by RADIAN lists daily emissions of toxic substances during a number of days in 1988. These data provided very limited insight into the seasonal variation of production at Ciba-Geigy.
- Production levels at the Ciba-Geigy plant were obtained from the EPA archives (Bowers & Anderson, 1981) for the entire time of its operation, representing production in pounds per year of dyestuffs, intermediates, anthraquinone, bleaches, resins, plastics, agrochemicals, etc. However, since the production level information provided by the facility is incomplete and does not reflect true emissions, these data were not used in the modeling. Since the production levels at Ciba-Geigy have significant gaps due to missing data, estimates of annual emissions based on these data would be inaccurate. To avoid these limitations, the approach followed in this analysis assumed a "nominal emissions rate" of 100 grams per second throughout the study period.

5.2.2 Stack Parameters for Ciba-Geigy

Two sources of information were used to retrieve stack parameters for the Ciba-Geigy plant: the National VOC Inventory and the NJDEP permit files. The National VOC Inventory, compiled by EPA using data supplied by NJDEP, dates from 1990 and only reflects pollutants and stack information for that year. By searching through NJDEP

permits for all of the Ciba-Geigy buildings, however, it was possible to approximate the number and characteristics of facility stacks from 1968 to 1991. These stack parameters are shown in Table 3 (Mayes, 2001). Although the latter source of information is incomplete, the alternative was to use the nationally-averaged Standard Industrial Classification (SIC) stack parameters. Such parameters represent the stack parameters of numerous plants from all parts of the country and may bear no resemblance to this particular facility.

5.2.3 Emissions from Oyster Creek Nuclear Generating Station

Quarterly summaries of the effluent release data for the Oyster Creek Nuclear Generating Station were compiled from NRC records for years from 1970 to 1998. The measured elevated effluent releases are separated into fission gases, iodines, particulate matter and radionuclides for the years 1980-1982 are illustrated in Appendix C in alphabetical order. Blank cells in the tables denote that a particular effluent was not measured for that quarter. Values of <MDL denote activity below the minimum detection limit, whereas values of <LLD indicate activity below the lower limit of detection. The detection limits used were not available from the facility. No uniformity in compound reporting was found between quarters of each year and a rationale was not given in the records provided to the NRC.

The monthly emission input factors used to generate the ambient gas concentrations were the NRC reported effluent gas release values for iodine 131. The monthly emission input factors used to generate the ambient particulate matter concentrations were the sum of the NRC reported effluent release values for cesium 137, cobalt 60, and strontium 90 combined. When only quarterly effluent release data were available, those values were divided by 3 and assigned to each month of the quarter. These cumulative effluent emissions reported by NRC for Oyster Creek Nuclear Generating Station are in units of Curie.

The effluent release values chosen reflected the most complete data sets available. There were many “gaps” in the data reported by the Oyster Creek nuclear plant; in general the most consistent reporting was for Iodine 131.

The stack parameters for Oyster Creek were provided by the facility as follows:

Stack Height (meters)	Temperature (degrees Kelvin)	Exit velocity (meters/second)	Stack diameter (meters)
115.8	299.82	2.58	1.0

5.3 NJDHSS Residence Location Data

The NJDHSS supplied a database (in Microsoft Access 97 format) of Ocean County residences locations, collected in the epidemiologic study for which estimates of the ambient gaseous and particulate concentrations were produced. The information in that database included only a study identification number and the latitude and longitude coordinates of the residence. No information on case or control status was provided by NJDHSS. To prepare the data in a format compatible with the ISCST3 model, the latitude and longitude coordinates were converted to Universal Transverse Mercator (UTM) coordinates using the software program CONCOR (US EPA, 2000). After

concentration estimates were calculated, the UTM coordinates were reconverted to latitude and longitude coordinates for reporting compatibility with the locations of the residences used in the modeling.

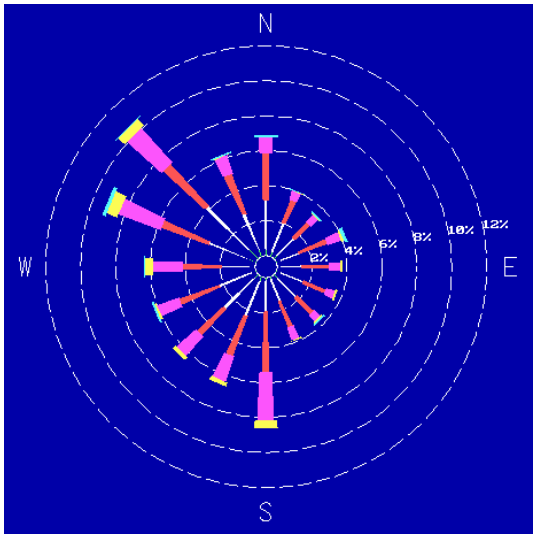
5.4 Model Outputs

The simulations for both Ciba-Geigy and Oyster Creek produced monthly-averaged estimates of the airborne concentrations of both gaseous and particulate matter. In addition, estimates of dry deposition of particles to the land surface were also generated. The ISCST3 model also includes algorithms to handle scavenging and removal by wet deposition of gases and particles. However, the estimation of wet deposition is more directly dependant upon the quality of the meteorological (precipitation) data than is the case for dry deposition estimation. As an example of the sporadic nature of precipitation, data for Atlantic City for the year 1997 show that 11.5% of the hours recorded some precipitation. Precipitation data are highly variable in a spatial sense too, and the direct use of Atlantic City data would inadequately represent the Dover Township area. No precipitation data are available for Lakehurst, however. Due to these limitations, the uncertainty inherent in estimating wet deposition was considered too great to merit its estimation. Furthermore, particles that are "rained out" quickly become part of the surface runoff and are not available later through resuspension, which can potentially be the case with dry deposited particles.

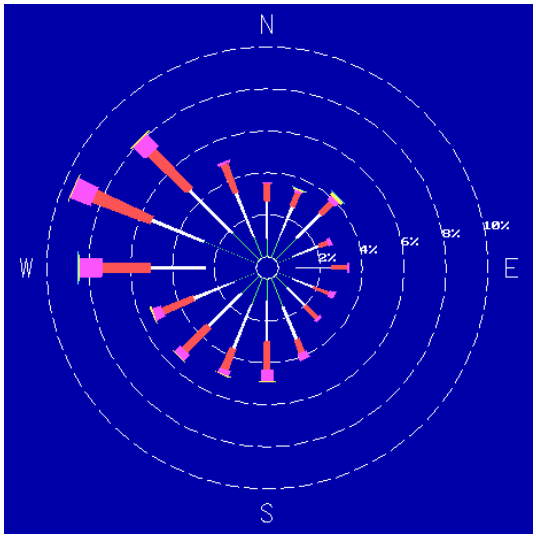
Since no release data pertaining to particle size or density existed, calculations were carried out for both Ciba-Geigy and Oyster Creek emissions using two particle sizes. A comparison of modeling estimates for Ciba-Geigy using particle sizes of 10 and 50 μm diameter showed very similar patterns at ground level. In the absence of valid on-site data, particle sizes corresponding to the cutoff values used in the National Ambient Air Quality Standards (NAAQS), namely 2.5 and 10 μm, were used for the Ciba-Geigy simulations. For Oyster Creek, personal communication with the facility (Vouglitos, 1999) highlighted that particle sizes were sampled for one day and indicated that particles were either less than 1.0 μm or greater than 10 μm; based on this information the sizes adopted for modeling particulate emissions from Oyster Creek were 0.5 and 15 μm.

Table 3. Stack parameters for Ciba-Geigy 1960-96

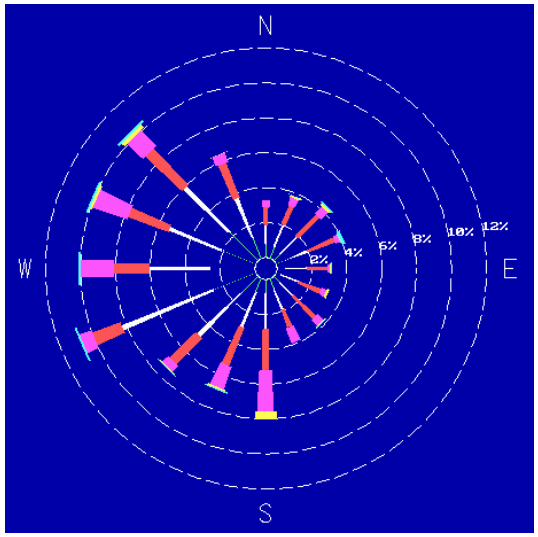
Year	Height	Temperature	Velocity	Diameter
	(meters)	(degrees K)	(m/sec)	(meters)
1960	24.38	310.93	10.16	0.36
1961	24.38	310.93	10.16	0.36
1962	24.38	310.93	10.16	0.36
1963	24.38	310.93	10.16	0.36
1964	24.38	310.93	10.16	0.36
1965	24.38	310.93	10.16	0.36
1966	24.38	310.93	10.16	0.36
1967	24.38	310.93	10.16	0.36
1968	24.38	310.93	10.16	0.36
1969	21.34	298.98	1.30	0.36
1970	21.34	300.16	1.11	0.36
1971	21.34	299.57	1.20	0.36
1972	21.34	299.87	1.16	0.36
1973	21.34	299.72	1.18	0.36
1974	23.11	306.23	6.42	0.36
1975	18.92	313.38	3.82	0.36
1976	18.92	313.38	3.82	0.36
1977	18.92	313.38	3.82	0.36
1978	19.81	299.82	1.23	0.36
1979	21.34	294.26	1.41	0.32
1980	21.34	294.26	1.41	0.32
1981	21.34	294.26	1.41	0.32
1982	21.34	294.26	1.41	0.32
1983	21.34	294.26	1.41	0.32
1984	21.34	294.26	1.41	0.32
1985	21.34	299.82	15.52	0.32
1986	21.34	299.82	15.52	0.32
1987	15.24	283.15	25.87	0.32
1988	15.24	283.15	25.87	0.32
1989	15.24	283.15	25.87	0.32
1990	15.24	283.15	25.87	0.32
1991	15.24	283.15	25.87	0.32
1992	15.24	283.15	25.87	0.32
1993	15.24	283.15	25.87	0.32
1994	15.24	283.15	25.87	0.32
1995	15.24	283.15	25.87	0.32
1996	15.24	283.15	25.87	0.32
SIC values	**26.20**	**308.00**	**18.00**	**0.88**



Atlantic City

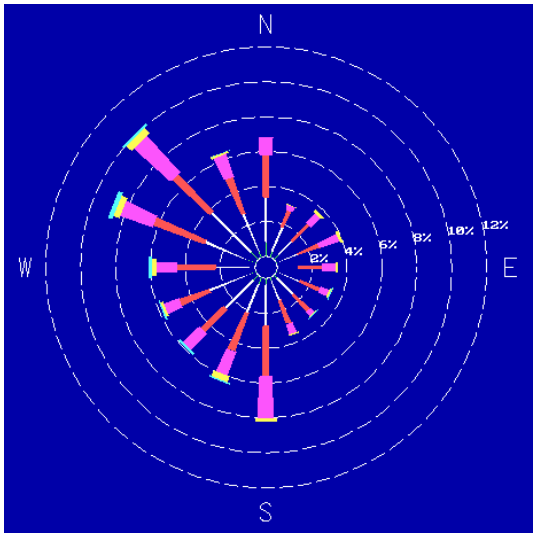


Lakehurst

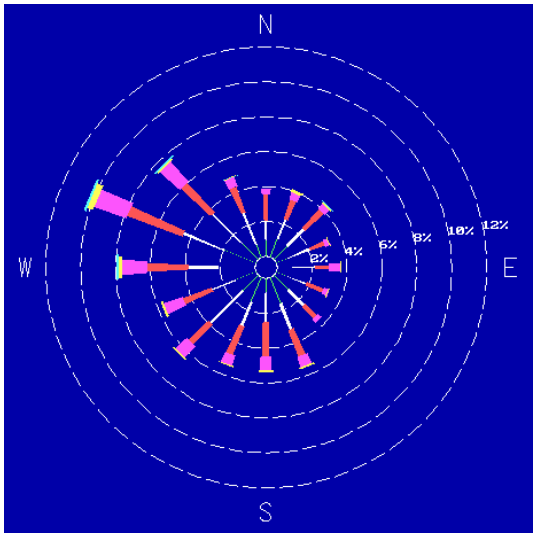


Oyster Creek

Figure 5. Spatial Variability of Windfields: 1984 Annual Wind Roses for the meteorological stations of Atlantic City, Lakehurst and Oyster Creek (see map in Figure 1)



Atlantic City



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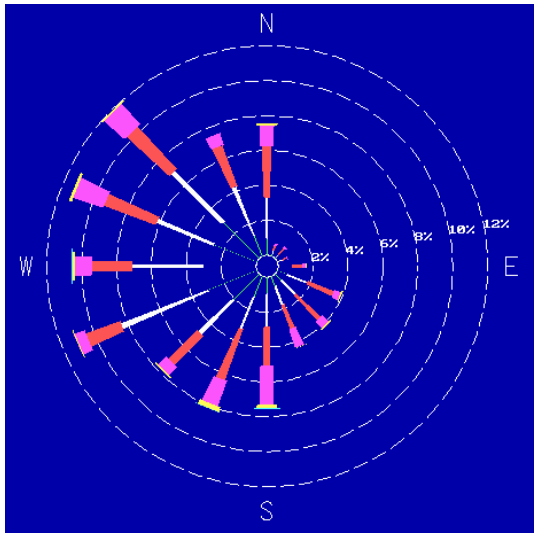


Oyster Creek

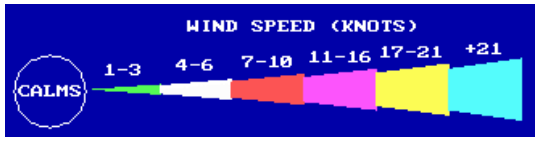


Figure 6. Spatial Variability of Windfields: 1986 Annual Wind Roses for the meteorological stations of Atlantic City, Lakehurst and Oyster Creek (see map in Figure 1)

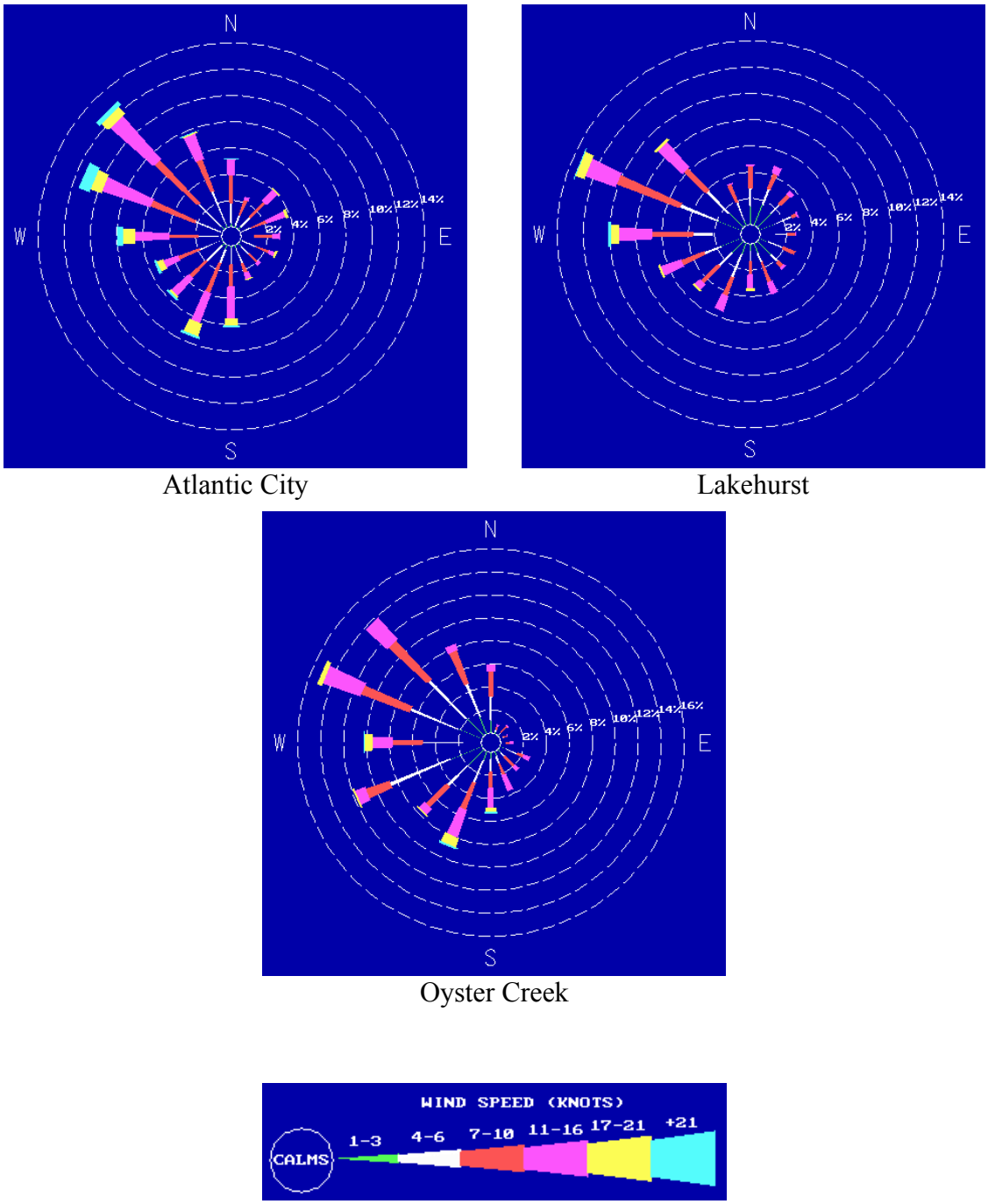


Figure 7. Spatial Variability of Windfields: 1986 Winter Wind Roses for the meteorological stations of Atlantic City, Lakehurst and Oyster Creek (see map in Figure 1)

6 DISCUSSION OF MODELING RESULTS

The complete set of results includes:

- Monthly averaged estimates of normalized ambient gaseous and particulate matter concentrations and total dry deposition amounts for each receptor (residence location) selected by NJDHSS, due to the Ciba-Geigy facility using a nominal emission rate and Atlantic City meteorological data.
- Monthly averaged estimates of normalized ambient gaseous and particulate matter concentrations and total dry deposition amounts for each receptor (residence location) selected by NJDHSS, due to the Ciba-Geigy facility, using a nominal emission rate and Lakehurst meteorological data.
- Monthly averaged estimates of normalized ambient gaseous and particulate matter concentrations and total dry deposition amounts for each receptor (residence location) selected by NJDHSS, due to the Oyster Creek Nuclear Generating Station using effluent release emissions reported to the NRC as inputs and Oyster Creek (or when available) Atlantic City meteorological data.

The modeling results were provided to NJDHSS as Microsoft Access 97 files, for each year of the study. Table 4 presents a sample of the modeling estimates.

The temporal trends of gas concentrations from the simulation of effluent releases from the Oyster Creek Nuclear Generating Station are depicted for 1970-1996 for a sample receptor in Figure 8 and for the average over all the receptors in Figure 9. The latter figure also provides, in addition to the average concentration over all receptors, temporal trends of maximum and minimum values of gas concentrations among all the receptors. The minimum calculated value of gas concentrations among all the receptors is practically zero for the entire duration.

The temporal trends of gas concentrations from the simulation of effluent releases from the Ciba-Geigy plant are depicted for 1962-1996 using both Atlantic City and Lakehurst meteorological data for a sample receptor in Figure 10 and for the average over all the receptors in Figure 11. The latter figure also provides temporal trends of maximum and minimum values of gas concentrations among all the receptors. The gas concentrations obtained from the ISCST3 model using Lakehurst meteorological data are also depicted for years 1973-1989 in Figure 10 and Figure 11. These illustrations show that the gas concentrations obtained by using Lakehurst meteorological data are generally comparable – and somewhat higher – than those obtained by using Atlantic City meteorological data.

Area maps of monthly average gas concentrations for Ciba-Geigy simulations are presented as examples for January 1984 [Figure 12(a) and Figure 12(c) using Lakehurst meteorological data; Figure 12(b) and Figure 12(d) using Atlantic City meteorological data] and for July 1986 [Figure 13(a) and Figure 13(c) using Lakehurst meteorological data and Figure 13(b) and Figure 13(d) using Atlantic City meteorological data]. The above area maps were produced from ISCST3 simulations using a dense rectangular 40km x 40km grid of receptors centered around the Ciba-Geigy plant, with a 100m resolution.

The area maps in panels (c) and (d) of these figures are the same as those in panels (a) and (b), but employ a different scale for the same range of colors in order to reveal local

vs. regional concentration patterns in greater detail. The area maps do indicate that somewhat higher values of gas concentration are obtained using Lakehurst meteorological data, especially for receptors away from the plant: nevertheless there is no obvious geographical (location) bias in the relative concentration magnitudes that are calculated.

To further understand the issue, the sensitivity of the ISCST3 model to meteorological inputs (Atlantic City and Lakehurst meteorological data) for Ciba-Geigy simulations is presented in the form of percentile comparison graphs of gas concentration as well as via Tukey difference-sum graphs of gas concentrations for the year 1984 in Figure 14 and, in Figure 15, for the year 1986. The 5th, 15th, 25th, 35th, 45th, 55th, 65th, 75th, 85th and 95th percentile values of gas concentration were obtained for all the regularly spaced rectangular grid receptors and for the entire year from the ISCST3 model output for Atlantic City as well as Lakehurst meteorological data. In general, it is apparent from both types of graphs that the values obtained from the model by using Lakehurst meteorological data are higher compared to those obtained with Atlantic City meteorological data; this is the case for both the 1984 and 1986 examples.

The sensitivity of the ISCST3 model with respect to the dry deposition process, for Ciba-Geigy simulations using Atlantic City meteorological data, is presented as percentile comparison graphs of gas/particle concentration as well as Tukey difference-sum graphs of gas/particle concentration for the years 1984 and 1986 in Figure 16 and Figure 17, respectively. There is very little difference in the percentile comparison graph as well as in the Tukey difference-sum graphs. The above feature indicates that the calculations are not very sensitive to dry deposition processes. All the percentile comparison graphs and Tukey sum-difference graphs were produced from ISCST3 simulations that employed a dense rectangular 40km x 40km grid of receptors centered around the Ciba-Geigy plant, with a 100m resolution. Finally, Appendix D provides results of comparison of the ISCST3 model estimates with estimates from the AERMOD model.

Table 4. An example of the ISCST3 model predictions.

			Ciba-Geigy (µg/m^3)			Oyster Creek (10E-12 µg/m^3)		
Location	Month	Year	Gas	PM 2.5um	PM 10um	Gas	PM 0.5um	PM 15um
2002	1	1978	109.74466	109.11291	109.94802	0.00624	0.00003	0.00003
2009	1	1978	15.40160	15.25303	15.37019	0.00300	0.00000	0.00000
2010	1	1978	3.78050	3.61329	3.62792	0.00213	0.00000	0.00000
2011	1	1978	5.70958	5.66992	5.68856	0.00357	0.00003	0.00003
2014	1	1978	3.54523	3.51761	3.52722	0.00348	0.00003	0.00003
2016	1	1978	10.10495	9.98575	10.02739	0.00360	0.00003	0.00003
2017	1	1978	4.78285	4.61102	4.62959	0.00372	0.00003	0.00003
2018	1	1978	3.77669	3.70690	3.72729	0.00147	0.00000	0.00000
2020	1	1978	5.44472	5.35337	5.37743	0.00189	0.00000	0.00000
2021	1	1978	9.70174	15.80402	15.99375	0.00642	0.00003	0.00003
2022	1	1978	3.56934	3.42252	3.43613	0.00219	0.00000	0.00000
2023	1	1978	6.00449	5.81723	5.84419	0.00369	0.00003	0.00003
2028	1	1978	3.53299	3.50558	3.51504	0.00327	0.00003	0.00003
2029	1	1978	3.13804	3.07539	3.09083	0.00114	0.00000	0.00000
2035	1	1978	3.08717	3.07841	3.09217	0.00141	0.00000	0.00000
2036	1	1978	2.59470	2.54967	2.56075	0.00123	0.00000	0.00000
2038	1	1978	3.80417	3.76835	3.78319	0.00156	0.00000	0.00000
2039	1	1978	8.97329	8.85771	8.92494	0.00243	0.00000	0.00000
2043	1	1978	9.02496	8.96042	8.98945	0.00375	0.00003	0.00003
2044	1	1978	29.05430	28.77178	28.90874	0.00639	0.00003	0.00003
2045	1	1978	3.62091	3.52324	3.53712	0.00186	0.00000	0.00000
2047	1	1978	2.10270	2.09062	2.09557	0.00405	0.00003	0.00003
2049	1	1978	3.70456	3.67595	3.68594	0.00348	0.00003	0.00003
2050	1	1978	2.99184	2.97139	3.00258	0.00426	0.00003	0.00003
2057	1	1978	4.49957	4.43999	4.45923	0.00240	0.00000	0.00000
2215	1	1978	9.20375	9.01002	9.06030	0.00315	0.00003	0.00003
2216	1	1978	3.84275	3.80035	3.81495	0.00168	0.00000	0.00000
2218	1	1978	3.32972	3.30622	3.32920	0.00564	0.00003	0.00003
2220	1	1978	3.20872	3.15216	3.16701	0.00117	0.00000	0.00000

10^{-12} µg/m^3 = 123.2285 femtoCurie/m^3 for Iodine 131

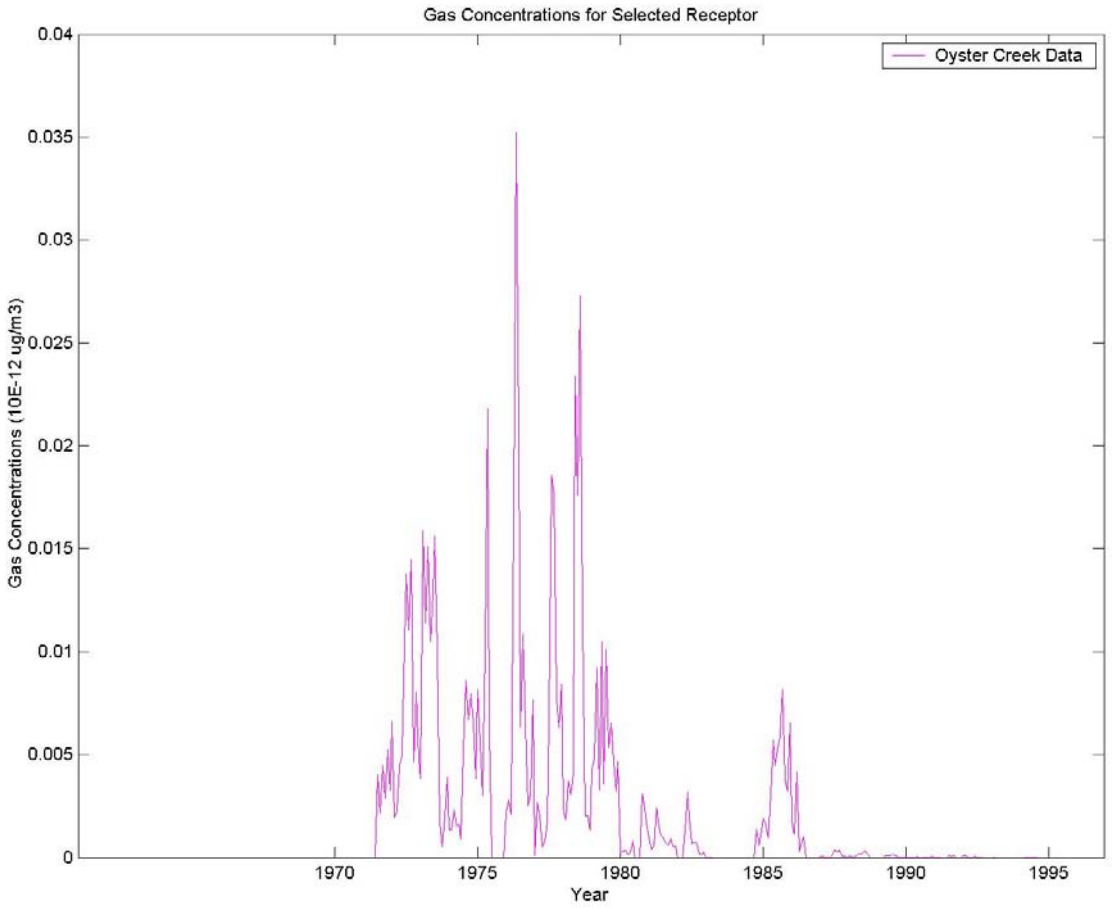


Figure 8. Temporal trends of gas concentrations (µg/m^3) for simulations of effluent releases from the Oyster Creek Nuclear Generating Station for a sample receptor for the period 1970-1996

10^{-12} µg/m^3 = 123.2285 femtoCurie/m^3 for Iodine 131

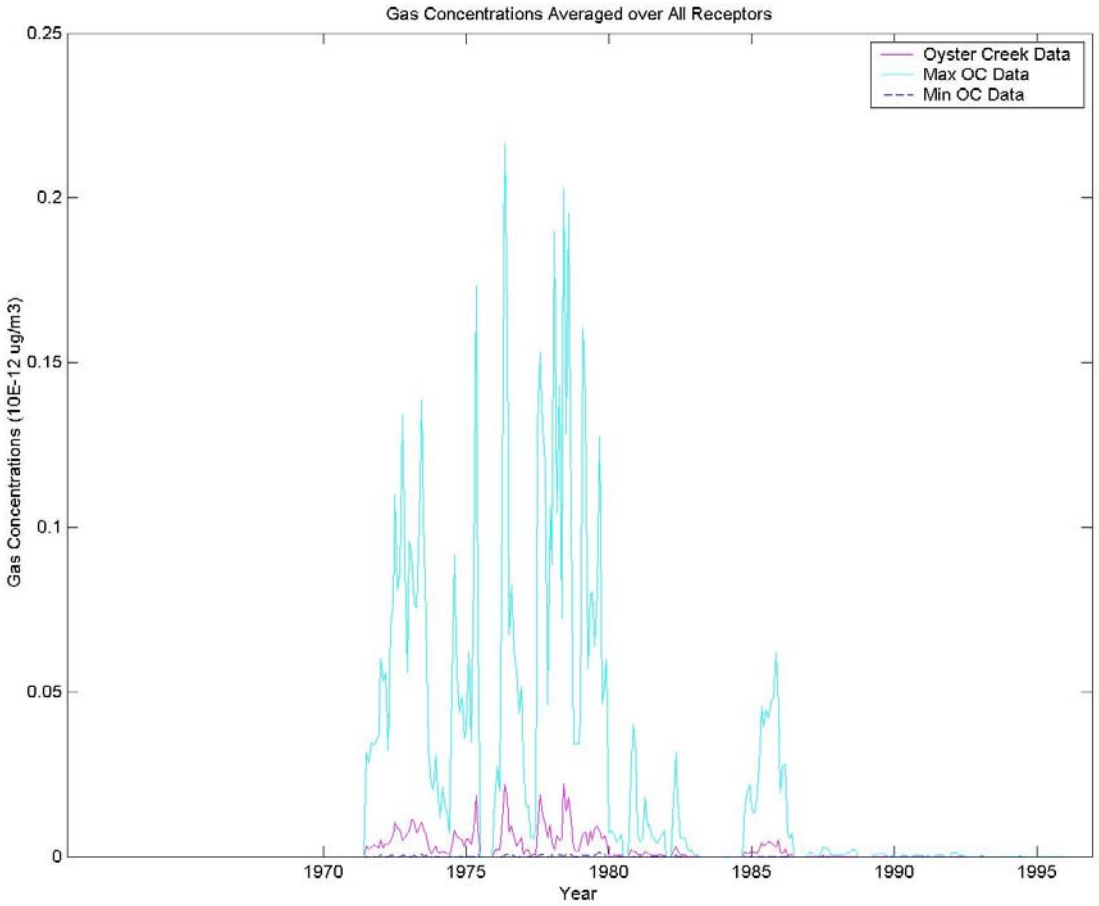


Figure 9. Temporal trends of gas concentrations (μg/m^3) for simulation of effluent releases from the Oyster Creek Nuclear Generating Station for the period 1970-1996.

The figure presents gas concentration estimates averaged over all the receptors, as well as the maximum and minimum value of gas concentrations among all the receptors, for the study period.

10^{-12} μg/m^3 = 123.2285 femtoCurie/m^3 for Iodine 131

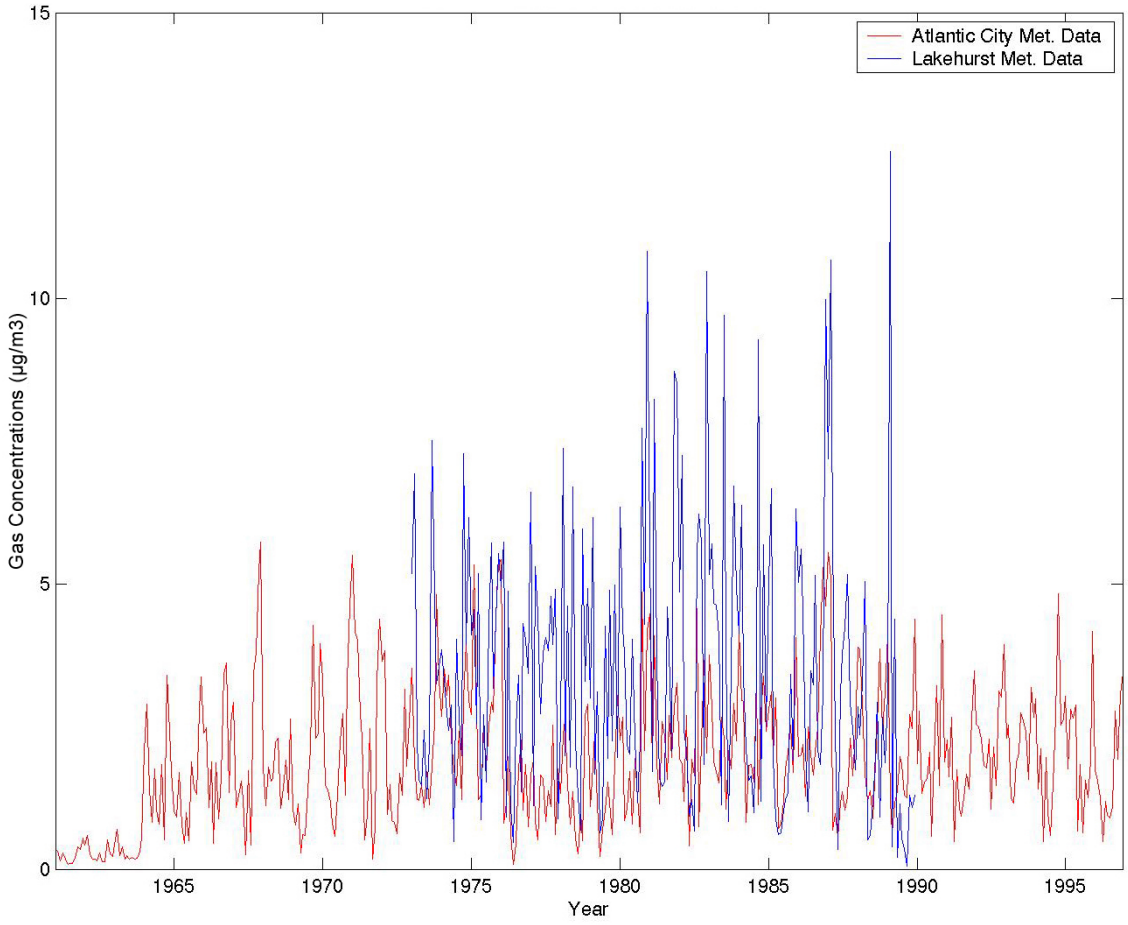


Figure 10. Temporal trends of gas concentrations (µg/m^3) for simulations of effluent releases from the Ciba-Geigy plant

The figure presents concentration estimates over the study period for a sample receptor using Atlantic City meteorological data (1962-1996) and Lakehurst meteorological data (1973-1989).

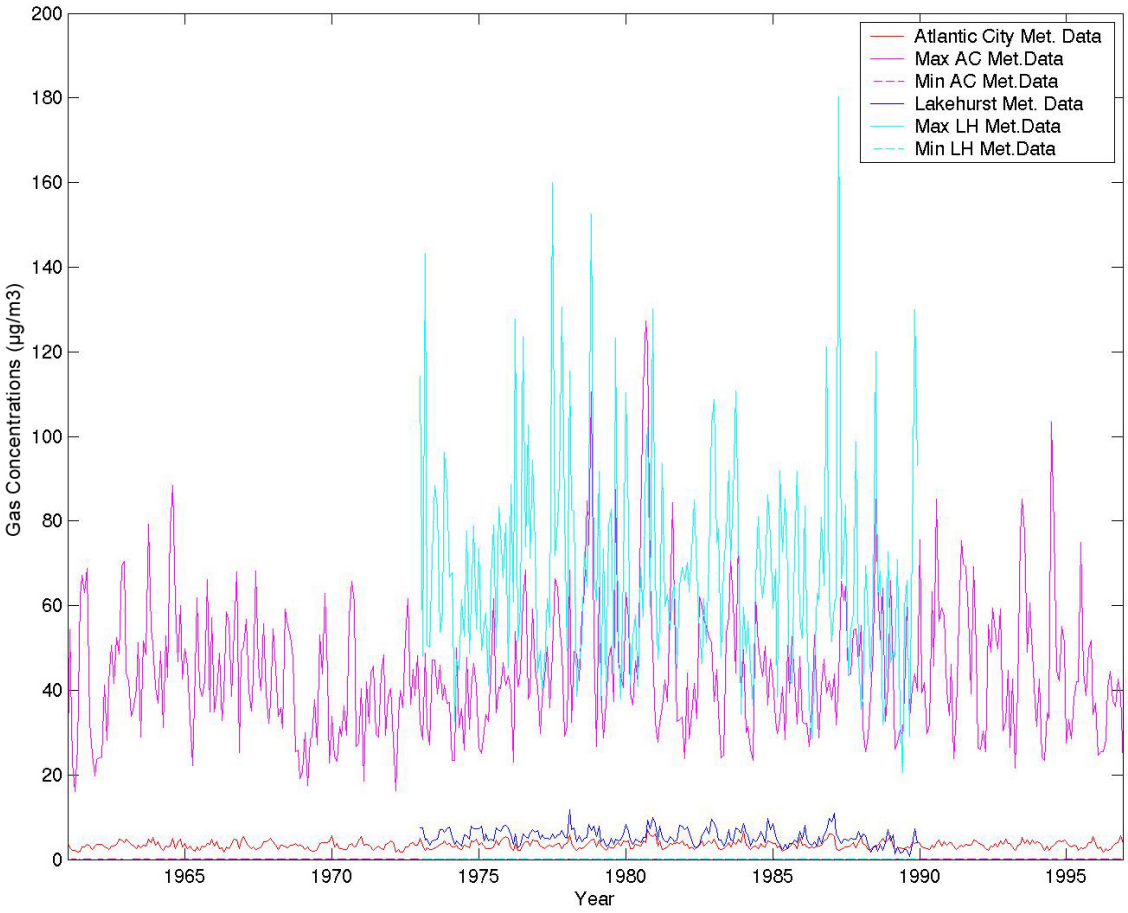


Figure 11. Temporal trends of gas concentrations (µg/m^3) from simulations of effluent releases with nominal emission rates from the Ciba-Geigy plant using Atlantic City meteorological data (1962-1996) and Lakehurst meteorological data (1973-1989)

The figure presents concentration estimates averaged over all the receptors, as well as the maximum and minimum value of gas concentrations among all the receptors, for the entire study period.

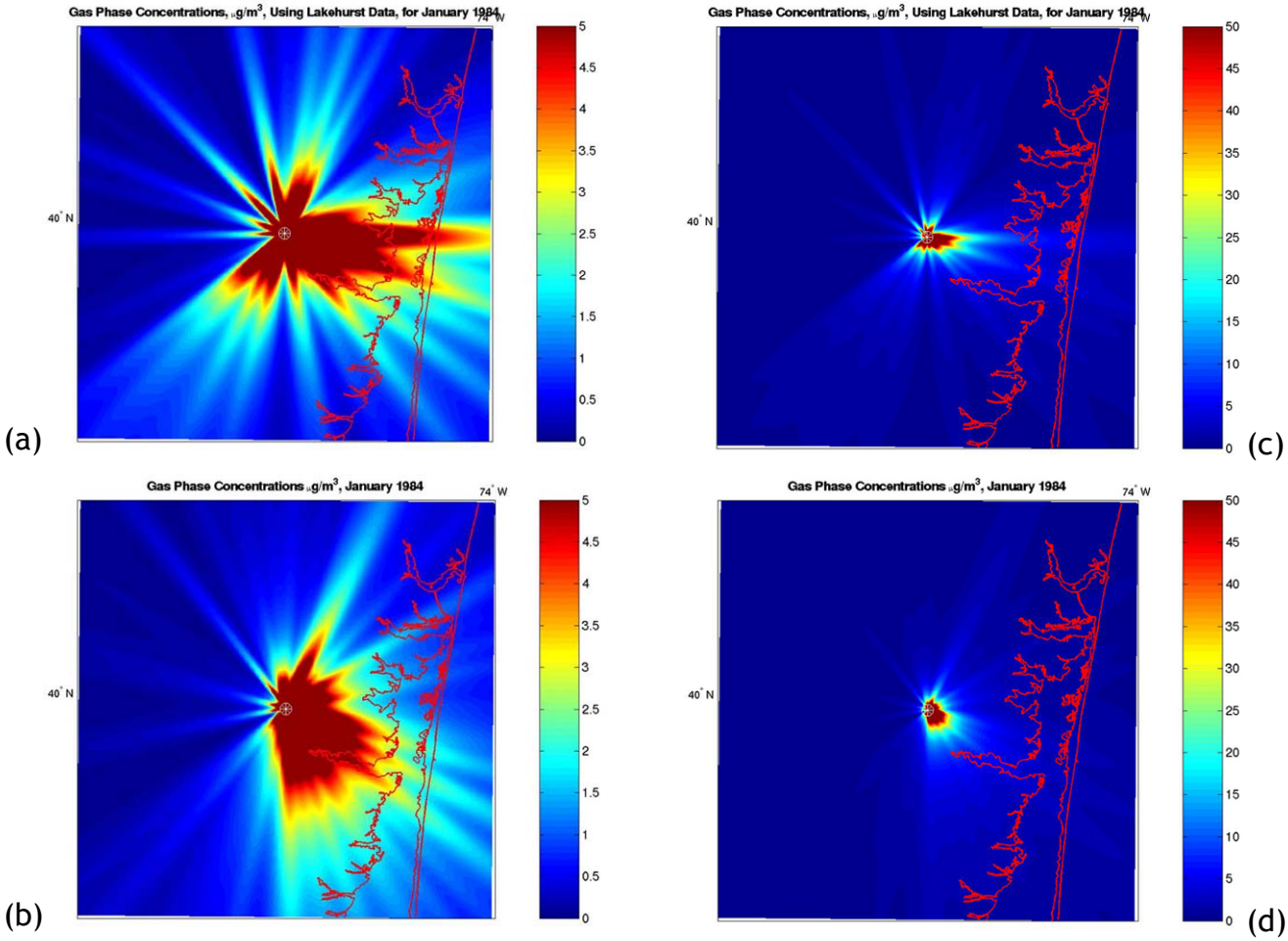


Figure 12. Area maps of the monthly average gas concentrations (μg/m^3) for simulations of effluent releases from the Ciba-Geigy plant for January 1984

Panel (a) uses Lakehurst meteorological data for January 1984 and panel (b) uses Atlantic City meteorological data for January 1984. Panels (c) and (d) provide the same information as panels (a) and (b), but employ a different scale for the same range of colors in order to reveal local vs. regional concentration patterns in greater detail.

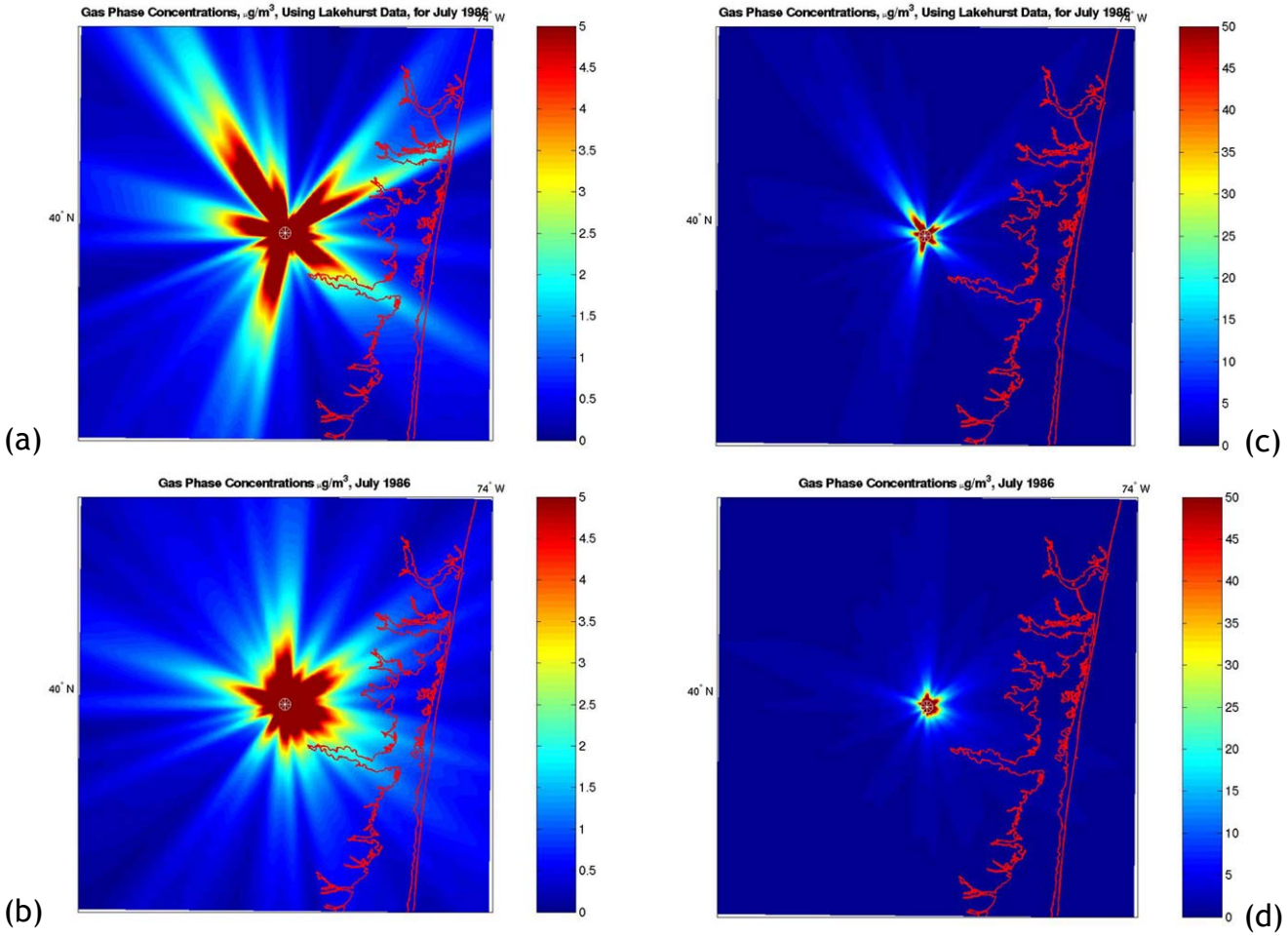


Figure 13. Area maps of the monthly average gas concentrations (μg/m^3) for simulations of effluent releases from the Ciba-Geigy plant for July 1986

Panel (a) uses Lakehurst meteorological data for July 1986 and panel (b) uses Atlantic City meteorological data for July 1986. Panels (c) and (d) provide the same information as panels (a) and (b), but employ a different scale for the same range of colors in order to reveal local vs. regional concentration patterns in greater detail.

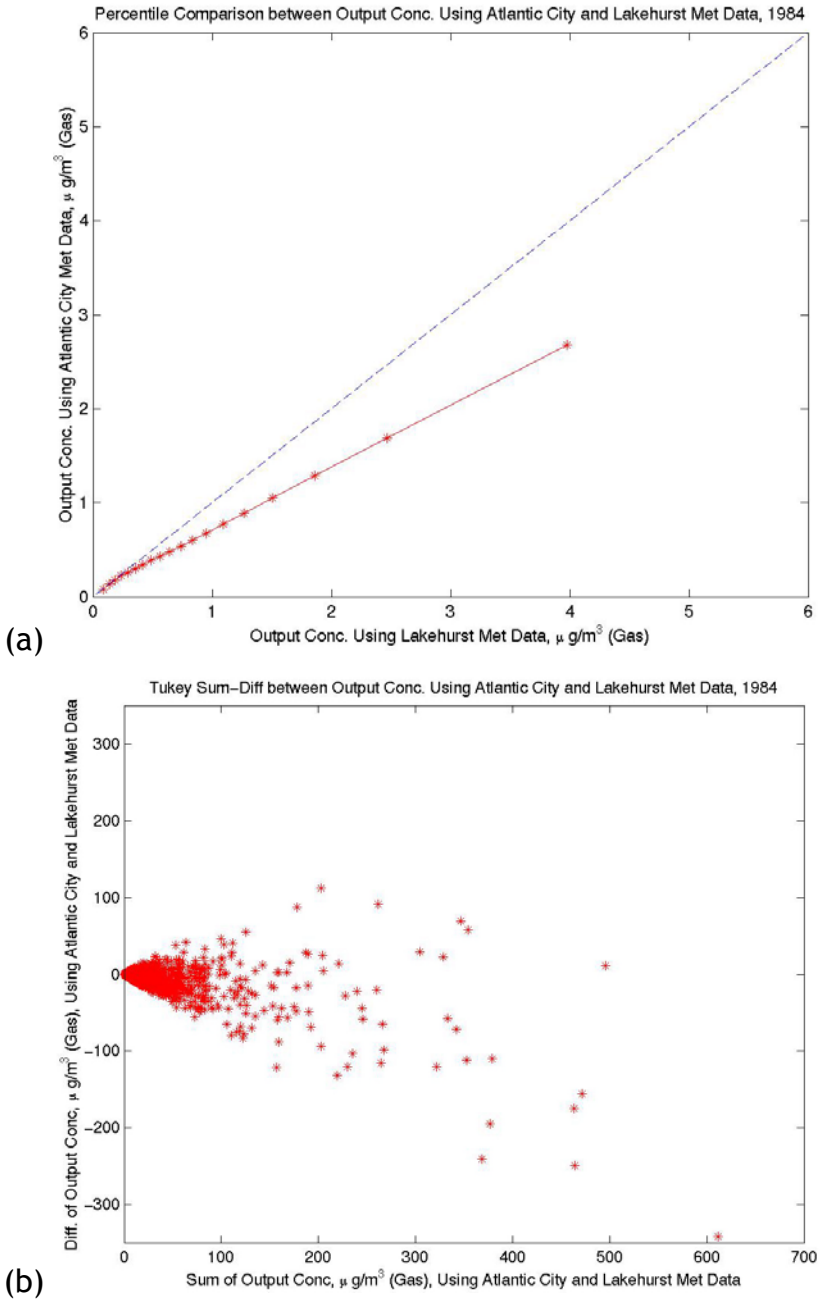
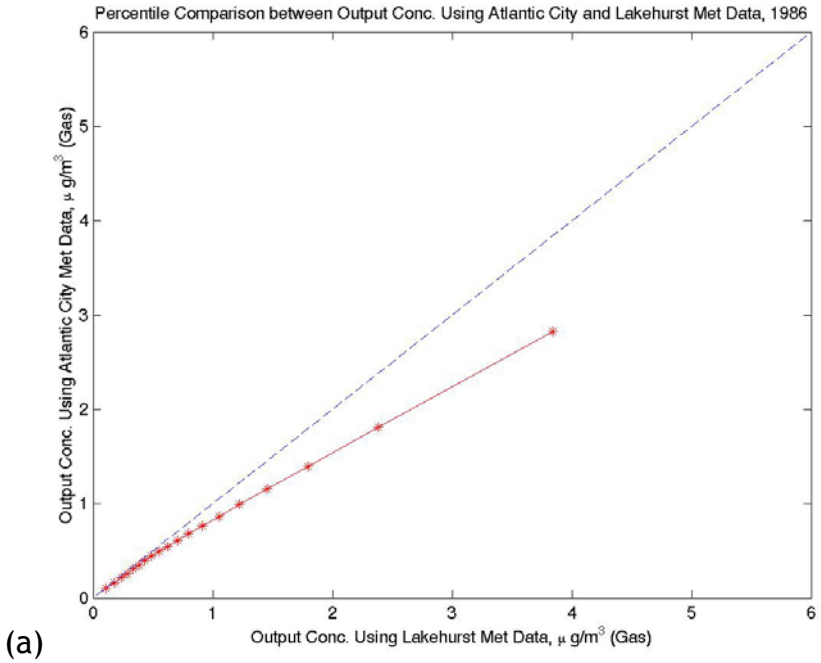


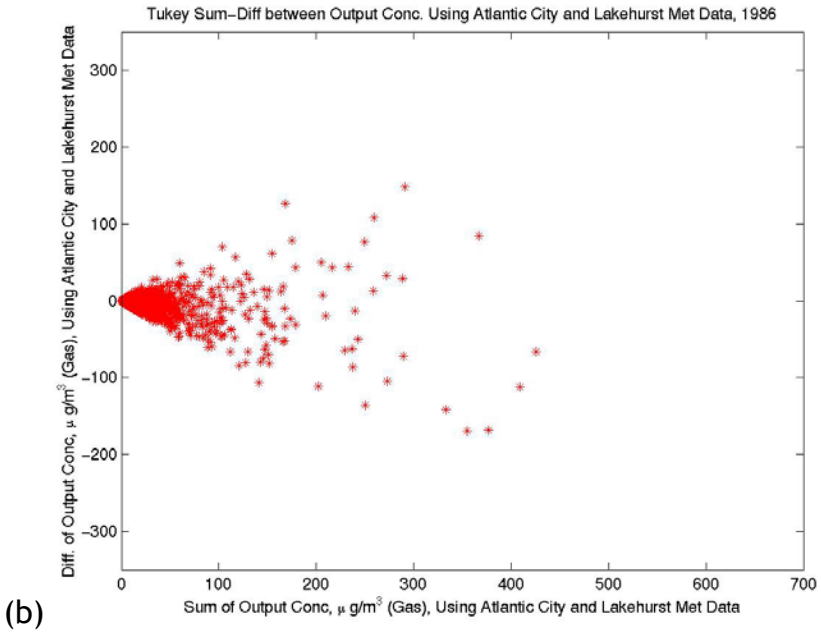
Figure 14. Model Sensitivity to Meteorological Inputs: Ciba-Geigy Emissions with Lakehurst vs. Atlantic City Inputs for 1984

(a) Percentile (5th, 15th, 25th, 35th, 45th, 55th, 65th, 75th, 85th and 95th) comparison graph of gas concentrations (µg/m^3) for 1984 for Ciba-Geigy simulations using Atlantic City meteorological data and Lakehurst meteorological data.

(b) Tukey difference-sum graph of gas concentrations (µg/m^3) for 1984 for Ciba-Geigy simulations using Atlantic City meteorological data and Lakehurst meteorological data.



(a)

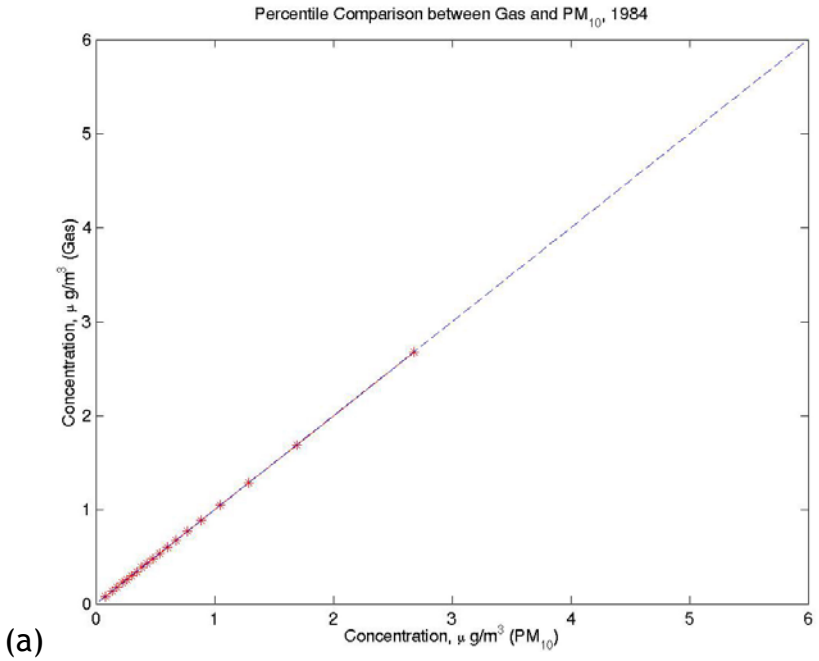


(b)

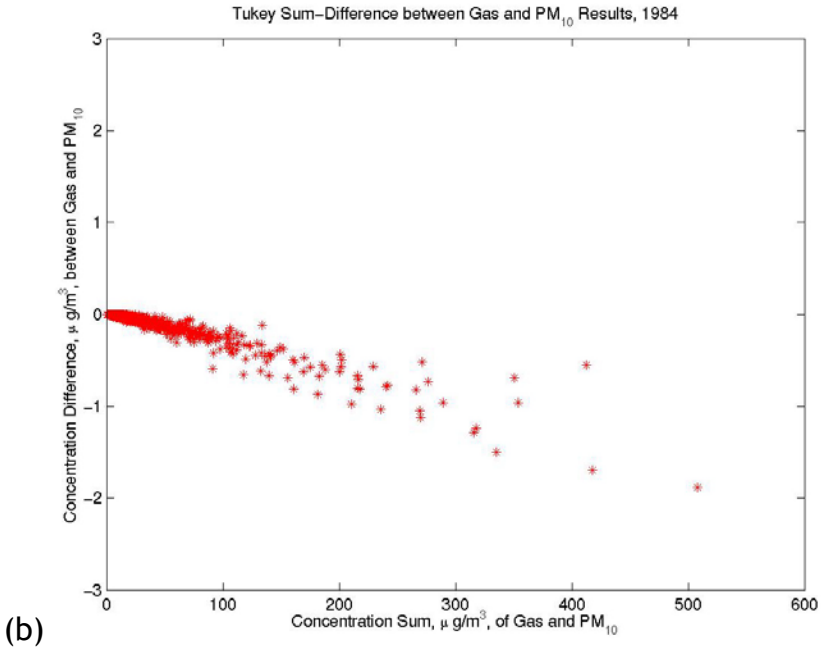
Figure 15. Model Sensitivity to Meteorological Inputs: Ciba-Geigy Emissions with Lakehurst vs. Atlantic City Inputs for 1986

(a) Percentile (5th, 15th, 25th, 35th, 45th, 55th, 65th, 75th, 85th and 95th) comparison graph of gas concentrations (μg/m^3) for 1986 for Ciba-Geigy simulations using Atlantic City meteorological data and Lakehurst meteorological data.

(b) Tukey difference-sum graph of gas concentrations (μg/m^3) for 1986 for Ciba-Geigy simulations using Atlantic City meteorological data and Lakehurst meteorological data.



(a)

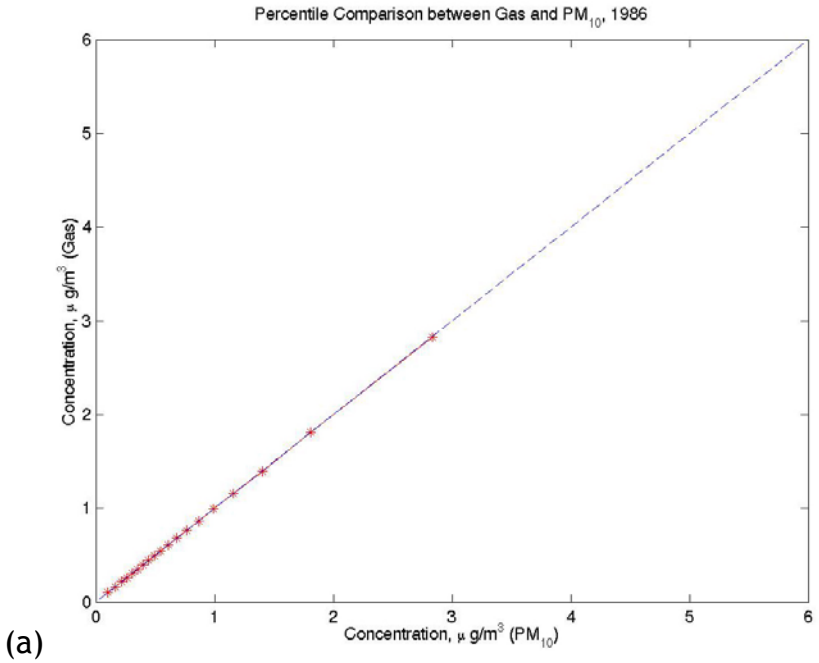


(b)

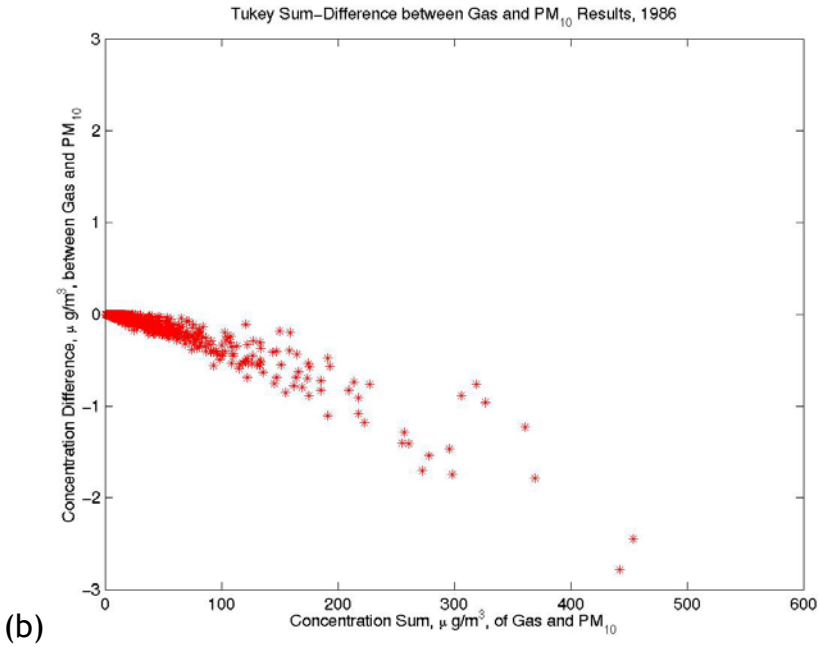
Figure 16. Model Sensitivity to Dry Deposition: Estimates for Nominal Ciba-Geigy Gas vs. PM_{10} Emissions for 1984

(a) Percentile (5th, 15th, 25th, 35th, 45th, 55th, 65th, 75th, 85th and 95th) values of gas concentrations ($\mu g/m^3$) and PM_{10} concentrations ($\mu g/m^3$) for 1984 for Ciba-Geigy simulations using Atlantic City meteorological data.

(b) Tukey difference-sum graph of gas concentrations ($\mu g/m^3$) and PM_{10} concentrations for 1984 for Ciba-Geigy simulations using Atlantic City meteorological data.



(a)



(b)

Figure 17. Model Sensitivity to Dry Deposition: Estimates for Nominal Ciba-Geigy Gas vs. PM_{10} Emissions for 1986

(a) Percentile (5th, 15th, 25th, 35th, 45th, 55th, 65th, 75th, 85th and 95th) values of gas concentrations ($\mu g/m^3$) and PM_{10} concentrations ($\mu g/m^3$) for 1986 for Ciba-Geigy simulations using Atlantic City meteorological data.

(b) Tukey difference-sum graph of gas concentrations ($\mu g/m^3$) and PM_{10} concentrations for 1986 for Ciba-Geigy simulations using Atlantic City meteorological data.

7 CONCLUSIONS

The objective of this study was to use the best available data to provide atmospheric dispersion estimates for the Dover Township area. In the absence of more precise data, what was possible was an assessment of the relative magnitude of outdoor concentrations over time within the area of concern[*].

[*] A sensitivity analysis considered the use of alternative meteorological data inputs, incorporation of dry deposition processes, and the use of alternative atmospheric dispersion models; the outcome of this analysis supports the generally accepted notion of the robustness of the Industrial Source Complex Short Term (ISCST3) model for this type of application.

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APPENDIX A IDENTIFICATION OF MAJOR EMITTERS IN OR NEAR THE AREA OF DOVER TOWNSHIP (1962-1996)

A.1 Introduction

Five sources of information were used to investigate possible emission points in and around Dover Township. These were as follows:

- United States Environmental Protection Agency's (US EPA) Aerometric Information Retrieval System (AIRS);
- US EPA's Toxic Release Inventory (TRI), available from US EPA and also the Right-To-Know Network (RTK NET, run by the OMB Watch and Unison Institute);
- New Jersey Department of Environmental Protection (NJDEP) volatile organic compounds (VOC) inventory;
- NJDEP air permit files;
- Oyster Creek effluent releases obtained from the Nuclear Regulatory Commission (NRC)

The AIRS database reflects the current year reported to US EPA by the States, in this case 1990. The TRI currently holds information from 1987 to 1996. The VOC inventory for each county produced by NJDEP reflects emissions for 1990 only, as do the permit records at NJDEP.

The AIRS database reports carbon monoxide, nitrogen dioxide and total VOCs for each stack at a facility. Since details regarding the nature of the pollutants are necessary for this modeling exercise, this source of information is of limited use. The TRI data, in contrast, lists the total emissions per pollutant but without reference to the facility stack(s). The VOC State Inventory lists facility and stack parameters but only those operational in 1990.

A.2 Results

A.2.1 Results from AIRS

The AIRS system lists the following facilities for Ocean County:

- Ciba-Geigy Corporation
- Atlantic City Electric Company
- Heritage Minerals Incorporated
- Paco Research Corporation
- Point Bay Fuel Inc.
- Fluid Packaging Co. Inc.
- The American Graphite Company
- Community Memorial Hospital

- Dover Oil Company
- GPU Nuclear Corporation
- Point Pleasant Hospital
- Toms River Regional School District
- Harris & Mallow Products Inc.
- Ocean County Utilities Authority
- United States Government
- Russo Fuel Inc.
- Pomona Oil Company
- J.W. Finley Inc.
- Seacoast Oil Company Inc.
- Dover Landfill Energy Corporation

The AIRS system does not report the length of time that these facilities have been operating and only reflects the situation in 1990. The current status of these facilities and their emissions is also not available.

A.2.2 Results from TRI

The TRI provides more extensive information than AIRS. The following list reflects all facilities in Ocean County that operated during the period 1987-1996, their emitted pollutants and amounts:

Facility/Pollutant	Stack Release (lbs)	Fugitive Release (lbs)
1987		
Ciba-Geigy Corporation		
Acetone	971	2339
Ammonia	1200	1200
Epichlorohydrin	14745	7552
Ethylene Glycol		250
Formaldehyde		134
Methanol20017	20017	5100
Methyl Ethyl Ketone	3196	928
Methyl Isobutyl Ketone	240	
4,4'-Methylenedianiline	320	
N-Butyl Alcohol	1136	
O-Cresol	182	
Toluene	99644	21748
Xylene	4598	630
Dixon Ticonderoga		
Xylene	500	500
Harris & Mallow		
Laquer Thinner	7000	3000
Laquer Topcoat/Sealers	1000	1000
Stains	12000	8000
Mainship Corporation		
Acetone	11558	
Styrene	1100	
Paco Pharmaceutical		
Hydrochloric Acid	250	250
Towico Electronics Inc.		
1,1,1-Trichloro`ethane	16325	

Facility/Pollutant	Stack Release (lbs)	Fugitive Release (lbs)
1988		
Ciba-Geigy Corporation		
Acetone	446	108
Epichlorohydrin	9113	1905
Formaldehyde	118	
Methanol	7652	1376
Methyl Ethyl Ketone	3450	2904
Methyl Isobutyl Ketone	675	85
4,4'-Methylenedianiline	290	53
N-Butyl Alcohol	2886	85
O-Cresol	113	
Toluene	98286	20533
Xylene	3324	697
Dixon Ticonderoga		
Xylene	500	500
Mainship Corporation		
Acetone	8884	
Styrene	1250	
Paco Pharmaceutical		
Hydrochloric Acid	250	250
Phosphoric Acid	250	250
Sodium Hydroxide	250	250
PMC Inc.		
1,1,1-Trichloroethane		3706
Towico Electronics Inc.		
1,1,1-Trichloroethane	17711	

Facility/Pollutant	Stack Release (lbs)	Fugitive Release (lbs)
1989		
Ciba-Geigy Corporation		
Acetone	671	132
Chromium Compounds	5	5
Epichlorohydrin	16222	2382
Formaldehyde	261	54
Methanol	11268	1919
Methyl Ethyl Ketone	3468	733
Methyl Isobutyl Ketone	547	68
4,4'-Methylenedianiline	479	
N-Butyl Alcohol	1708	
O-Cresol	200	
Toluene	131127	10882
Xylene	2337	481
Dixon Ticonderoga		
Xylene	500	500
Paco Pharmaceutical		
Hydrochloric Acid	250	250
Phosphoric Acid	250	250
Towico Electronics Inc.		
1,1,1-Trichloroethane	12506	

Facility/Pollutant	Stack Release (lbs)	Fugitive Release (lbs)
1990		
Ciba-Geigy Corporation		
Acetone	906	80
Ammonia	5	5
Chromium Compounds	5	5
Copper Compounds	250	5
Dibutyl Phthalate	5	5
Diethanolamine	5	5
Epichlorohydrin	8277	866
Formaldehyde	169	5
Hydrazine	5	5
4,4'-Isopropylidenediphenol	5	5
Methanol	9590	53
Methyl Ethyl Ketone	2767	230
Methyl Isobutyl Ketone	300	12
4,4'-Methylenedianiline	439	5
N-Butyl Alcohol	8465	5
O-Cresol	67	5
Phosphoric Acid	5	5
Phthalic Anhydride	5	5
Toluene	67407	12000
Xylene	3174	800
Dixon Ticonderoga		
Xylene	750	750
Paco Pharmaceutical		
Hydrochloric Acid	250	250
Phosphoric Acid	250	250
Sulfuric Acid	250	250
Permacel		
Toluene	1032	424
Xylene		950
PMC Inc.		
1,1,1-Trichloroethane		8155
Towico Electronics Inc.		
1,1,1-Trichloroethane	13425	

Facility/Pollutant	Stack Release (lbs)	Fugitive Release (lbs)
1991		
Church & Co.		
Ammonia		15
Copper Compounds	8	
Ciba-Geigy Corporation		
Ammonia		15
Copper Compounds	8	
Dixon Ticonderoga		
Xylene	750	750
Paco Pharmaceutical		
Hydrochloric Acid	250	250
Phosphoric Acid	250	250
Sulfuric Acid	250	250
Permacel		
Toluene	546	451
Xylene	442	
PMC Inc.		
1,1,1-Trichloroethane		8820
SS White Burs Inc		
Freon 113		9830
Towico Electronics Inc.		
1,1,1-Trichloroethane	14771	
1992		
Dixon Ticonderoga		
Xylene	750	750
Paco Pharmaceutical		
Phosphoric Acid	250	250
Sulfuric Acid	250	250
Permacel		
Toluene	564	5
Xylene	352	5
PMC Inc.		
1,1,1-Trichloroethane		4410
SS White Burs Inc		
Freon 113		11900
Towico Electronics Inc.		
1,1,1-Trichloroethane	10796	

Facility/Pollutant	Stack Release (lbs)	Fugitive Release (lbs)
1993		
Ciba-Geigy Corporation		
Cobalt Compounds	8	
Copper Compounds	14	
Dixon Ticonderoga		
Xylene	750	750
Paco Pharmaceutical		
Phosphoric Acid	250	250
Sulfuric Acid	250	250
Permacel		
Toluene	473	
SS White Burs Inc		
Freon 113		18800
Towico Electronics Inc.		
1,1,1-Trichloroethane	6021	
1994		
Ciba-Geigy Corporation		
Chromium Compounds	21	
Cobalt Compounds	13	
Copper Compounds	15	
Dixon Ticonderoga		
Xylene	750	750
Paco Pharmaceutical		
Phosphoric Acid	250	250
Sulfuric Acid	250	250
Permacel		
Toluene	581	
Xylene	267	
SS White Burs Inc		
Freon 113		16405

Facility/Pollutant	Stack Release (lbs)	Fugitive Release (lbs)
1995		
Ciba-Geigy Corporation		
Chromium Compounds	12	
Cobalt Compounds	4	
Copper Compounds	8	
Dixon Ticonderoga		
Xylene	250	250
Paco Pharmaceutical		
Phosphoric Acid	250	250
Permacel		
Toluene	537	
Xylene	392	
SS White Burs Inc		
Freon 113		17420
1996		
Ciba-Geigy Corporation		
Chromium Compounds	3	
Cobalt Compounds	2	
Copper Compounds	8	
N-Methyl-2-Pyrrolidone	2	
Dixon Ticonderoga		
Xylene	250	250
Permacel		
Toluene	132	
Xylene	90	

Note: Some of these facilities were operating before 1987.

A.3 Results from NJDEP Air Permits

In order to ascertain the start-up dates of operation of the facilities listed above, it was necessary to search NJDEP air permits. Air permits for the Ciba-Geigy facility were found extending back to 1968. Other facility air permits were not located.

According to NJDEP Field Staff with experience in Dover Township, no other major emitters were known to exist in the 1960s or 1970s (Jones, 1999).

A.4 Conclusion

Based on the definition used by NJDEP for the emission of hazardous air pollutants (HAP), which states that an emitter is considered major if the releases are >10 tons per year (tpy) of an individual HAP, or >25 tpy for all HAPs, it can be concluded from the above information that only the Ciba-Geigy Corporation can be considered a major emitter in the Dover Township area. However, the Oyster Creek Nuclear Generating Station can also be considered to be an emitter of concern due to the nature of its types of releases (e.g. radionuclides) and its relative proximity to Dover Township.

APPENDIX B INPUT PARAMETERS FOR PCRAMMET FOR PARTICULATE DEPOSITION

Surface roughness

Surface roughness length is a measure of the height of obstacles to the wind flow. However it is not equal to the physical dimensions of the obstacles but is proportional to them. Typical values for a range of land use types as a function of season are available in tabular form in the PCRAMMET user's guide (US EPA, 1999b).

Monin-Obukhov length

The Monin-Obhukov length is a measure of atmospheric turbulence and atmospheric stability. It is negative during the day when surface heating results in an unstable atmosphere and positive during the night when the surface cools, contributing to a stable atmosphere.

During the daytime, convective, unstable conditions estimates of the heat flux are based on the formulation of Holtslag and van Ulden (Holtslag & van Ulden, 1983) which utilizes cloud cover, surface temperature, Bowen ratio and albedo data. Once the heat flux is computed, the friction velocity and the Monin-Obhukov length are determined through an iterative procedure which utilizes surface layer similarity.

During stable conditions, estimates of friction velocity and a temperature scale are made from cloud cover, wind speed and temperature. This in turn provides estimates of the heat flux and the Monin Obhukov length is determined from the knowledge of heat flux and the friction velocity (Venkatram, 1980).

Bowen ratio*

The Bowen ratio is a measure of the amount of moisture at the surface. The presence of moisture at the earth's surface can modify the sensible heat flux and alter the energy balance. Typical values of Bowen ratio as a function of land use types, seasons and moisture conditions are available in tabular form in the PCRAMET user's guide (US EPA, 1999b).

Anthropogenic heat flux

The anthropogenic heat flux cannot be ignored in areas of high population densities or high energy use, viz., highly urbanized locations. Oke (Oke, 1978) presents estimates of the anthropogenic heat flux for different seasons on the basis of population density and per capita energy use for 10 different cities; these are utilized to estimate anthropogenic heat flux.

Noon-time albedo

The noon time albedo is defined as a fraction of the incoming solar radiation that is reflected from the ground when the sun is directly overhead. Typical values of noon time

*The ratio of the amount of sensible to that of latent heat lost by a surface to the atmosphere by the processes of conduction and turbulence.

albedo as a function of land use type and season are available in tabular form in the PCRAMMET user's guide (US EPA, 1999b).

Fraction of net radiation

Fraction of net radiation absorbed at the ground is estimated on the basis of parameterization suggested by Oke (Oke, 1982).

Table 5. Input requirements for PCRAMMET based on urban land-use for particulate deposition

(*NJDEP, 1997*)

Surface roughness length *(measurement site)*	1.0 meters
Surface roughness length *(application site)*	1.0 meters
Noontime albedo	0.207
Bowen ratio	1.625
Anthropogenic heat flux	0.0 w/m^2
Minimum Monin-Obukhov length	25.0 meters
Fraction of net radiation absorbed by ground	0.22
Anemometer height	9.0 meters

**Winter albedo depends upon whether a snow cover is present continuously, intermittently, or seldom. Albedo ranges from about 0.30 for bare snow cover to about 0.65 for continuous cover.*

APPENDIX C COMPILATION OF EMISSIONS DATA RELEVANT TO THE ATMOSPHERIC DISPERSION MODELING FOR OYSTER CREEK

		First Quarter 1980	Second Quarter 1980	Third Quarter 1980	Fourth Quarter 1980
	Compound Released	Quantity (Ci)	Quantity (Ci)	Quantity (Ci)	Quantity (Ci)
Fission Gases	Kr 85 m			1.88E+02	6.22E+02
	Kr 87			7.44E+02	2.06E+03
	Kr 88			6.57E+02	2.02E+03
	Kr 89				
	Xe 133			9.16E+01	3.21E+02
	Xe 133 m				
	Xe 135			1.14E+03	3.42E+03
	Xe 135 m			4.80E+02	1.94E+03
	Xe 137			<MDL	2.00E+00
	Xe 138			1.72E+03	2.81E+02
Iodines	I 131			4.97E-01	2.24E-01
	I 132				
	I 133			2.19E+00	5.94E-01
	I 134				
	I 135			3.44E+00	8.43E-01
Particulates	Ba 140			3.71E-02	1.29E-01
	Ce 141			1.13E-04	1.38E-04
	Ce 143				
	Ce 144			<MDL	1.02E-03
	Co 58				
	Co 60			1.48E-03	8.75E-04
	Cr 51			5.84E-04	2.36E-03
	Cs 134			<MDL	7.10E-05
	Cs 137			7.68E-04	2.81E-03
	Fe 59			1.79E-04	<MDL
	Gross A				
	I 131			6.13E-03	8.32E-03
	I 133			9.89E-02	8.19E-02
	I 135			2.58E-01	1.81E-01
	La 140			3.29E-02	1.04E-01
	Mn 54			2.99E-04	<MDL
	Mo 99			9.24E-03	1.10E-02
	Na 24				
	Nb 95				
	Np 239			2.80E-03	1.12E-03
	Pa 233				
	Sr 89			2.05E-02	8.30E-02
	Sr 90			2.98E-05	8.87E-04
	Sr 91			3.88E-01	1.01E+00
	Tc 99 m			1.73E-01	2.68E-01
	Zr 95				
Radionuclides	H3				

		First Quarter 1981	Second Quarter 1981	Third Quarter 1981	Fourth Quarter 1981
	Compound Released	Quantity (Ci)	Quantity (Ci)	Quantity (Ci)	Quantity (Ci)
Fission Gases	Kr 85 m	3.89E+02	5.19E+02	4.49E+02	5.63E+02
	Kr 87	1.50E+03	1.87E+03	1.72E+03	1.90E+03
	Kr 88	1.24E+03	1.37E+03	1.68E+03	1.56E+03
	Kr 89	MDL	1.67E-01	<MDL	<MDL
	Xe 133	2.02E+02	3.00E+02	2.52E+02	2.73E+02
	Xe 133 m	3.32E+01	MDL	<MDL	<MDL
	Xe 135	2.33E+03	3.22E+03	3.12E+03	3.28E+03
	Xe 135 m	1.00E+03	1.27E+03	2.26E+02	1.14E+03
	Xe 137	1.43E+03	3.88E+00	<MDL	<MDL
	Xe 138	4.59E+03	4.21E+03	2.60E+03	3.91E+03
Iodines	I 131	1.68E-01	2.59E-01	1.84E-01	1.94E-01
	I 132				
	I 133	7.71E-01	9.36E-01	5.74E-01	8.83E-01
	I 134				
	I 135	1.15E+00	1.17E+00	9.97E-01	1.23E+00
Particulates	Ba 140	1.35E-01	1.05E-01	2.84E-02	4.67E-01
	Ce 141	4.07E-04	1.22E-04	1.81E-04	<MDL
	Ce 143	1.38E-03	MDL		
	Ce 144	9.92E-04	5.29E-04	1.44E-04	3.24E-02
	Co 58	7.76E-04	1.90E-04	4.14E-04	6.26E-05
	Co 60	1.04E-03	7.66E-04	1.36E-03	5.56E-04
	Cr 51	2.22E-03	6.71E-04		
	Cs 134				
	Cs 137	1.28E-03	9.78E-04	1.32E-03	3.74E-02
	Fe 59				
	Gross A				
	I 131	1.12E-02	1.54E-03	5.73E-03	7.21E-02
	I 133	1.07E-01	1.54E-02	2.66E-02	2.64E-02
	I 135	2.03E-01	2.25E-02	2.78E-02	4.58E-03
	La 140	1.11E-01	7.65E-02	2.10E-02	3.28E-01
	Mn 54	3.87E-03	6.02E-03	4.70E-03	3.19E-03
	Mo 99	1.13E-02	MDL		
	Na 24				
	Nb 95	4.96E-03	MDL	<MDL	1.46E-04
	Np 239	2.62E-03	9.33E-03		
	Pa 233	9.89E-05	MDL		
	Sr 89	4.36E-02	3.21E-02	1.78E-01	2.18E-01
	Sr 90	1.94E-03	2.66E-03	9.15E-04	1.32E-03
	Sr 91	5.94E-01	4.87E-01	1.82E-01	1.72E+00
	Tc 99 m	2.79E-01	3.35E-03	3.68E-03	1.67E-02
	Zr 95			<MDL	2.12E-04
Radionuclides	H3				

		First Quarter 1982	Second Quarter 1982	Third Quarter 1982	Fourth Quarter 1982
	Compound Released	Quantity (Ci)	Quantity (Ci)	Quantity (Ci)	Quantity (Ci)
Fission Gases	Kr 85 m	<MDL	4.68E+02	1.33E+02	3.76E+02
	Kr 87	<MDL	1.79E+03	3.72E+02	1.16E+03
	Kr 88	<MDL	1.48E+03	6.63E+02	1.13E+03
	Kr 89	<MDL	<MDL	<MDL	8.19E-04
	Xe 133	<MDL	3.12E+02	6.52E+01	1.97E+02
	Xe 133 m	<MDL	<MDL	<MDL	<MDL
	Xe 135	<MDL	2.93E+03	7.17E+02	2.54E+03
	Xe 135 m	<MDL	1.07E+03	3.72E+02	3.60E+02
	Xe 137	<MDL	6.84E+02	1.61E+02	5.33E-02
	Xe 138	<MDL	3.43E+03	1.20E+03	1.28E+03
Iodines	I 131	3.74E-04	7.24E-01	1.07E-01	3.86E-02
	I 132				
	I 133	2.17E-05	2.80E+00	5.69E-01	2.05E-01
	I 134				
	I 135	<MDL	4.27E+00	9.48E-01	3.01E-01
Particulates	Ba 140	<MDL	8.74E-02	2.11E-02	9.32E-03
	Ce 141	<MDL	1.37E-03	1.25E-04	2.14E-04
	Ce 144	4.46E-05	4.30E-04	9.94E-05	8.66E-05
	Co 57	<MDL	7.64E-06		
	Co 58	<MDL	1.99E-03	2.43E-04	1.45E-04
	Co 60	5.66E-04	1.04E-03	2.61E-04	2.68E-04
	Cr 51			<MDL	1.39E-04
	Cs 134			7.71E-05	<MDL
	Cs 137	1.94E-04	4.11E-04	3.30E-04	4.75E-05
	Fe 59	<MDL	1.07E-03	3.94E-04	2.11E-04
	Gross A				
	I 131	<MDL	5.33E-03	3.18E-03	1.27E-03
	I 133	<MDL	7.99E-02	4.11E-02	1.41E-02
	I 135	<MDL	2.13E-01	9.43E-02	2.43E-02
	La 140	<MDL	4.47E-02	1.69E-02	8.50E-03
	Mn 54	6.35E-05	1.21E-02	3.01E-03	1.62E-03
	Mo 99	<MDL	6.25E-03		
	Na 24				
	Nb 95			5.80E-05	<MDL
	Np 239	<MDL	3.16E-03	1.01E-04	<MDL
	Sr 89	6.21E-04	7.90E-03	7.80E-03	2.81E-03
	Sr 90	1.22E-05	3.69E-04	7.49E-05	5.37E-05
	Sr 91	<MDL	1.23E-01	1.71E-01	1.28E-01
	Tc 99 m	<MDL	2.23E-02	1.81E-02	3.20E-03
Radionuclides	H3				

***Note**: Converting Curie (disintegrations/second) to grams for iodine 131 introduces a factor of 8.115E-6 (utilizing half life of iodine 131 equal to 6.93E+5 and molecular weight of iodine 131 equal to 132.04769). Furthermore, accounting for cumulative release over a three-month period introduces another factor of approximately 1.286E-7. So, the overall conversion factor for Iodine 31 (emissions and gas phase concentrations) is 1.093E-12.*

APPENDIX D COMPARISON OF ISCST3 AND AERMOD MODELING ESTIMATES

Although the ISCST3 model, which represents the current EPA-recommended approach for the type of problems considered, was utilized in this study, it is useful to compare the estimates of ISCST3 with those of the new AMS/EPA regulatory model, AERMOD (US EPA, 1998h). Figure 18 illustrates the AERMOD modeling framework, depicting inputs, preprocessors, main components, as well as output characteristics. AERMOD has a provision to utilize the rawinsonde upper air meteorological data as well as the USGS terrain data. The comparison of ISCST3 and AERMOD model results for the Ciba-Geigy simulations using Atlantic City meteorological data in terms of percentile comparison graphs and Tukey difference-sum graphs of gas concentration are presented in Figure 19 and Figure 20 for the years 1984 and 1986, respectively. In the AERMOD simulations a flat terrain was assumed, hence only upper air rawinsonde meteorological data were used for the AERMOD run in addition to the data used for the ISCST3 simulations. The percentile comparison graph clearly reveals that AERMOD produces generally higher gas concentration values as compared to ISCST3. It is apparent from the Tukey sum-difference graph that the differences between AERMOD and ISCST3 (both using Atlantic City meteorological data) are comparable to the differences between the ISCST3 model runs with Atlantic City and Lakehurst meteorological data. The percentage differences of gas concentrations from Ciba-Geigy simulations between AERMOD and ISCST3 as area maps for January 1984, July 1984, January 1986 and July 1986 using Atlantic City meteorological data are depicted in Figure 21. All the percentile comparison graphs and Tukey sum-difference graphs were produced from ISCST3 simulations using a dense rectangular 40km x 40km grid of receptors centered around the Ciba-Geigy plant, with a 100m resolution, while the AERMOD simulations used a 40km x 40km grid of receptors with a 2000m resolution, due to restrictions in the format of receptor grid accepted by this model.

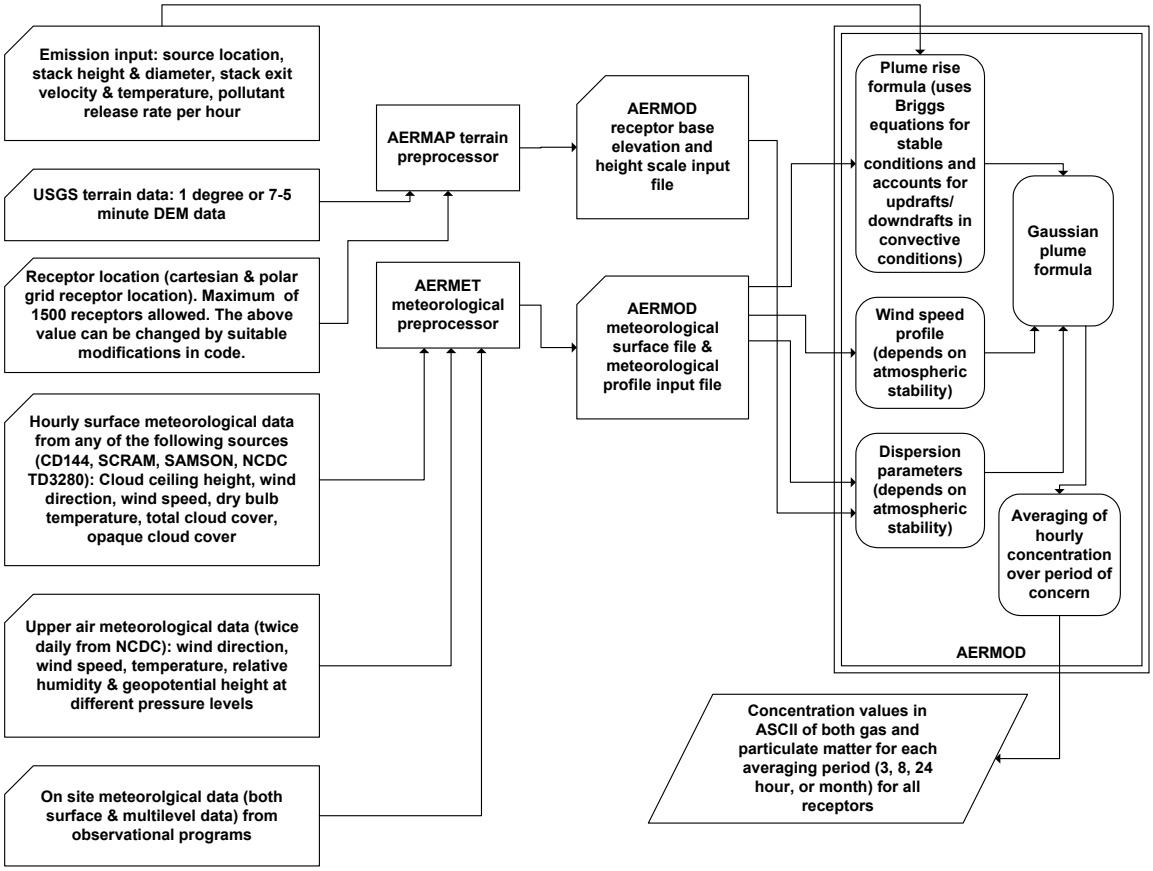
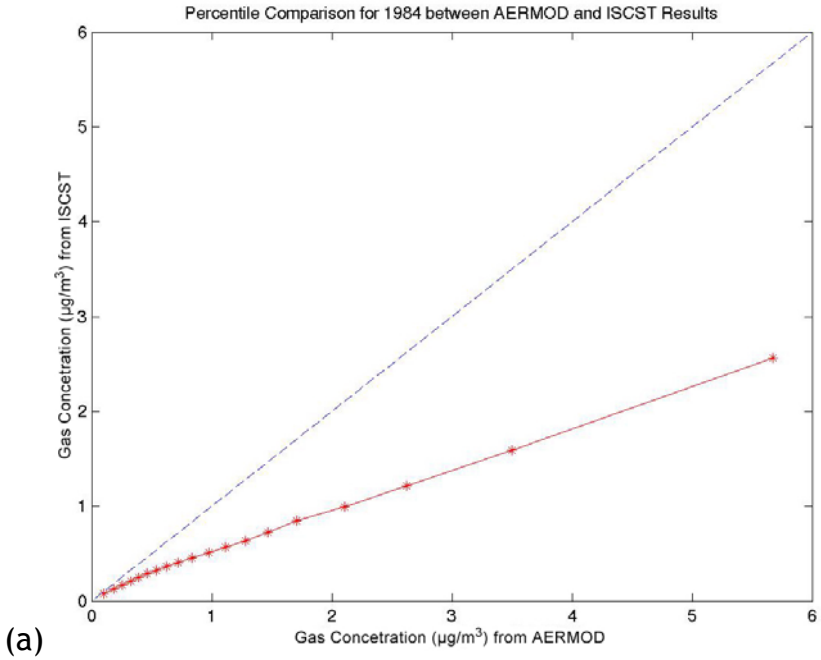
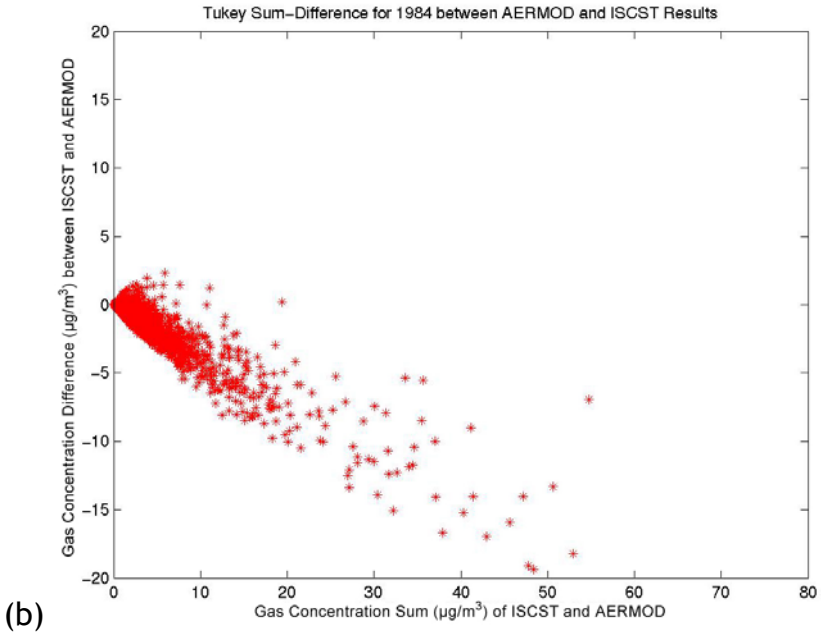


Figure 18. AERMOD modeling framework depicting inputs, preprocessors with components, and attributes of outputs



(a)

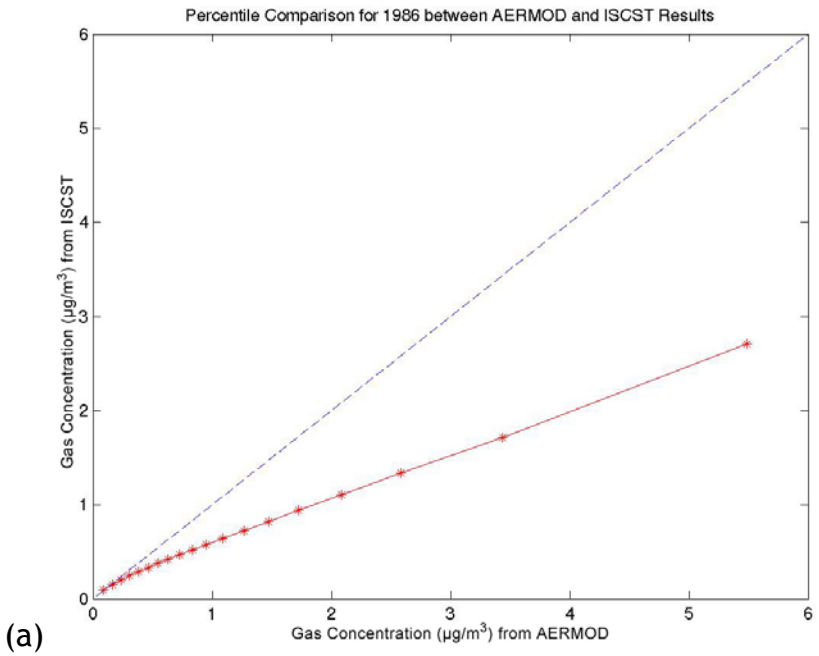


(b)

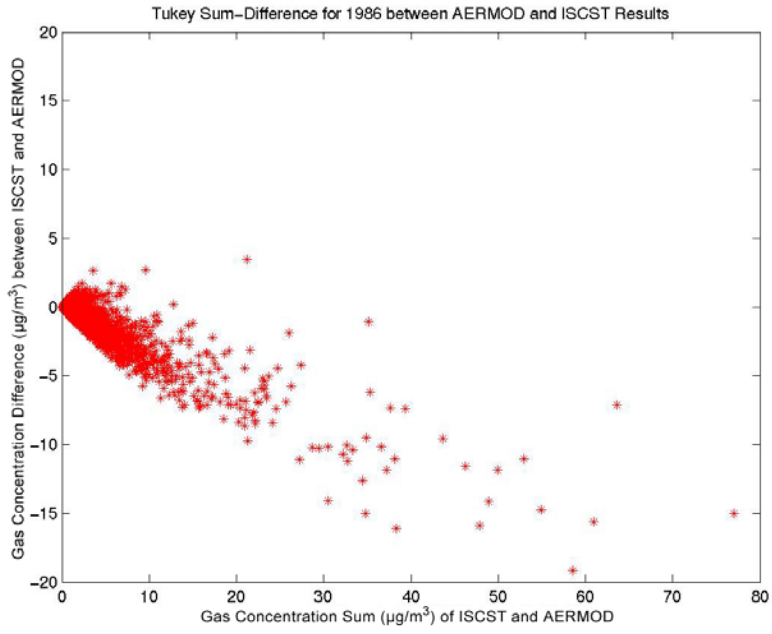
Figure 19. Comparison of ISCST3 and AERMOD Estimates: Ciba-Geigy Emissions with Atlantic City Meteorological Inputs for 1984

(a) Percentile (5th, 15th, 25th, 35th, 45th, 55th, 65th, 75th, 85th and 95th) comparison graph of gas concentrations (µg/m^3) using ISCST3 and AERMOD for 1984 for Ciba-Geigy simulations using Atlantic City meteorological data.

(b) Tukey difference-sum graph of gas concentrations (µg/m^3) using ISCST3 and AERMOD for 1984 for Ciba-Geigy simulations using Atlantic City meteorological data.



(a)



(b)

Figure 20. Comparison of ISCST3 and AERMOD Estimates: Ciba-Geigy Emissions with Atlantic City Meteorological Inputs for 1986

(a) Percentile (5th, 15th, 25th, 35th, 45th, 55th, 65th, 75th, 85th and 95th) comparison graph of gas concentrations (µg/m^3) using ISCST3 and AERMOD for 1986 for Ciba-Geigy simulations using Atlantic City meteorological data.

(b) Tukey difference-sum graph of gas concentrations (µg/m^3) using ISCST3 and AERMOD for 1986 for Ciba-Geigy simulations using Atlantic City meteorological data.

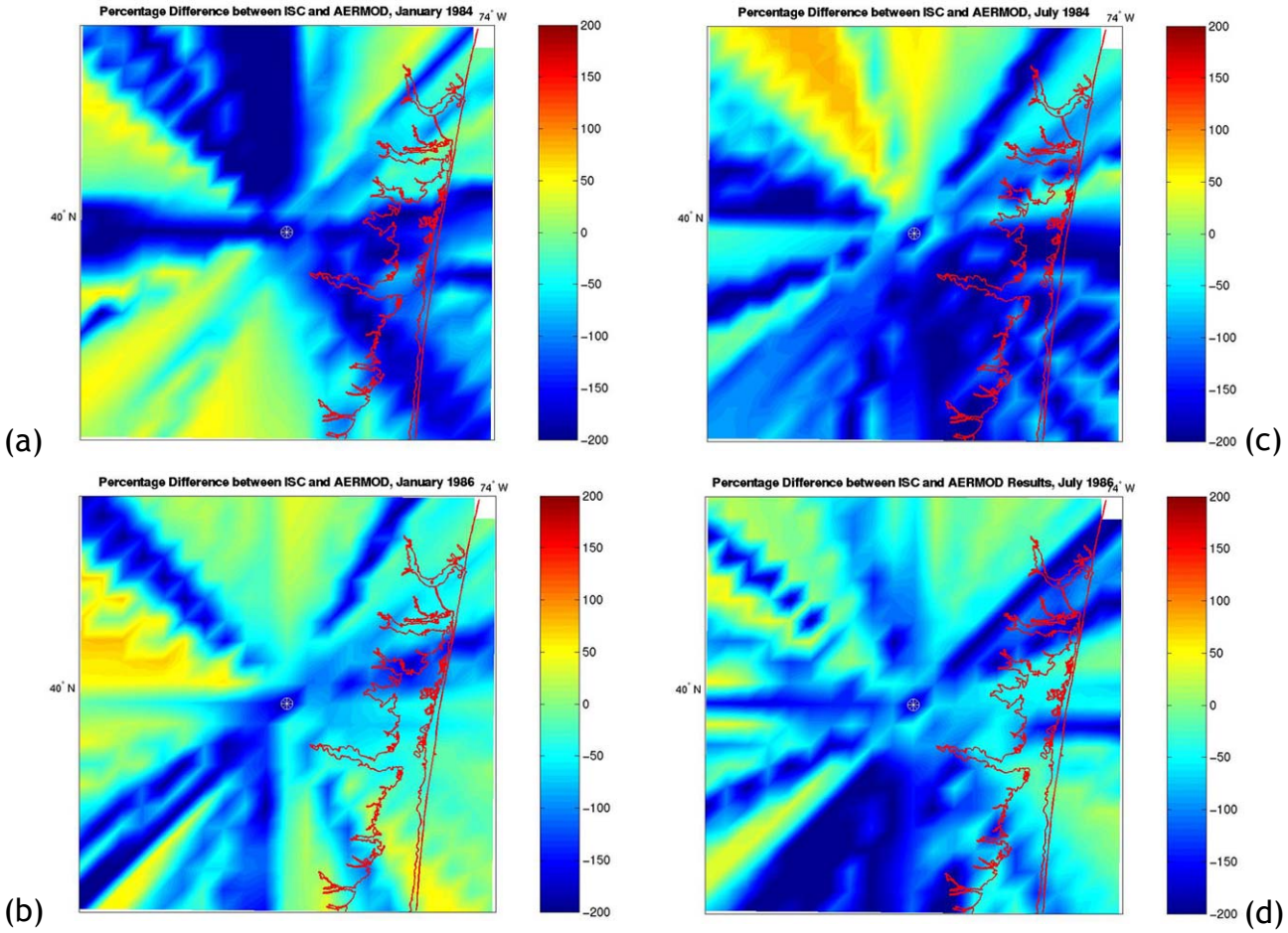


Figure 21. Area maps of percentage difference of gas concentrations (µg/m^3) between ISCST3 and AERMOD for Ciba-Geigy simulations using Atlantic City meteorological data for (a) January 1984; (b) January 1986; (c) July 1984; and (d) July 1986