Synthesis, Integration & Analysis of Meteorological & Air Quality Data

Jay Haney & Sharon Douglas

ICF International, San Rafael, California

Presented at the 25th Information Transfer Meeting

OCS Region of the Minerals Management Service

8 January 2009

New Orleans, Louisiana

Co-Authors:

Belle Hudischewskyj & Yihua Wei

ICF International, San Rafael, CA

Joe Adlhoch & Betsy Davis-Noland

Air Resource Specialists, Inc. (ARS), Fort Collins, CO

Presentation Outline

- Background & Objectives
- Project Overview
- Gulf of Mexico Air Quality Database (GMAQDB)
  - Overview of the database
  - Features & functionality of the database tool
- Data “Mining” & Analysis Results
- Reports Listing

Background

- MMS, together with the oil and gas industry, has collected a variety of meteorological, air quality & emissions data for the Gulf of Mexico (GOM) region
- The data span the years 1988 to present, and have been used to support various air quality related data analysis and modeling activities
- The amount and type of data varies throughout the period and a fully integrated assessment of the data had not been conducted

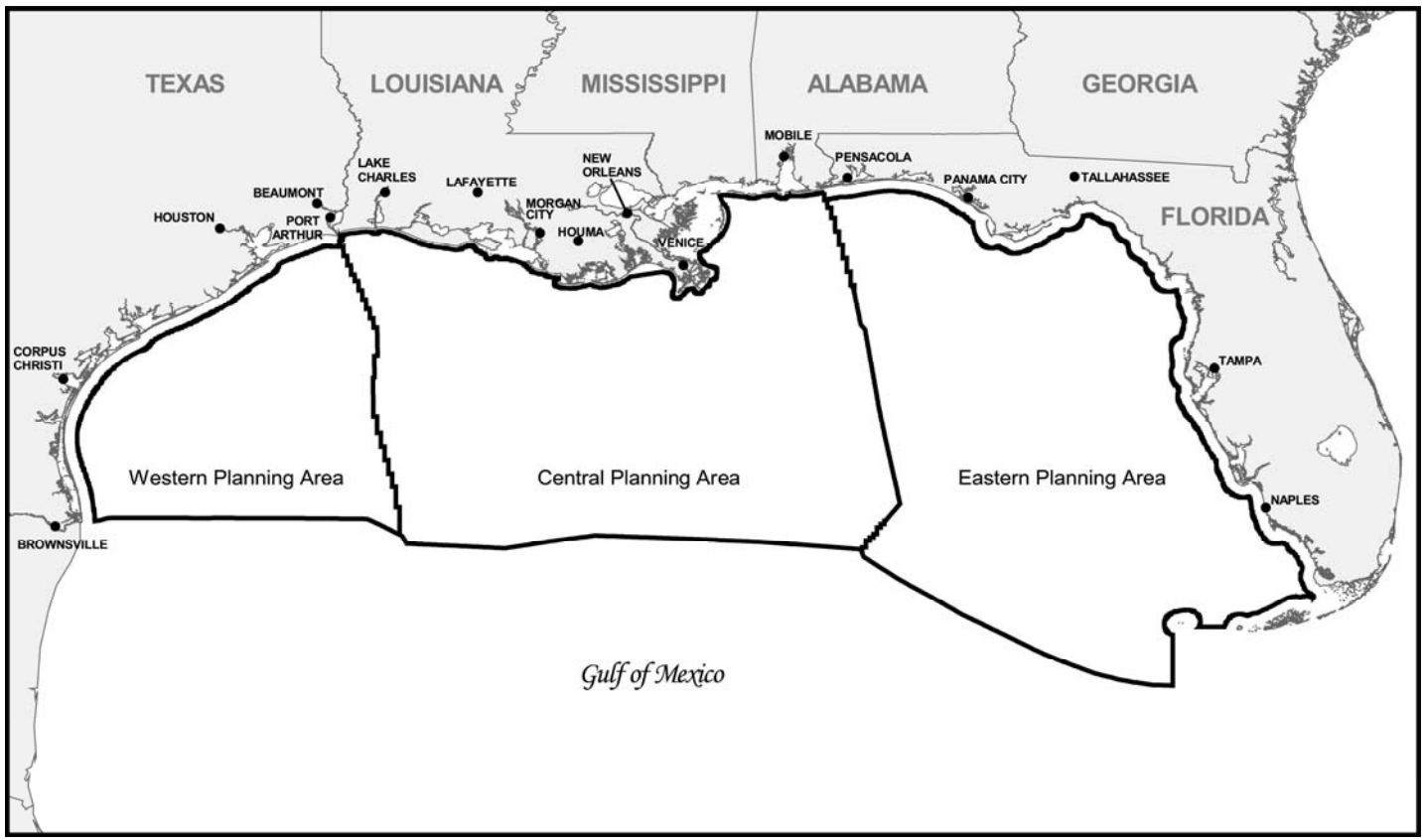
Key Objectives of the Data Synthesis & Integration Study

- Assemble meteorological, emissions & air quality data for the GOM region into a coherent dataset so that the data can be more fully "mined" to
  - Provide an improved understanding of the relationships between meteorology, emissions & air quality in the region
  - Support future regulatory data & modeling analyses related to ozone, fine particulate matter (PM2.5) & regional haze
- Conduct selected air quality data analyses

Project Overview

- Key technical elements of the study:
  - Establish & maintain a Science Review Group (SRG)
  - Design & develop an integrated database
  - Design & conduct basic data analyses that make use of the integrated dataset to examine air quality issues for the GOM region
  - Document the study

MMS Data Synthesis Study Area & Period



Database includes routine & “special studies” data for the period 1990–2004

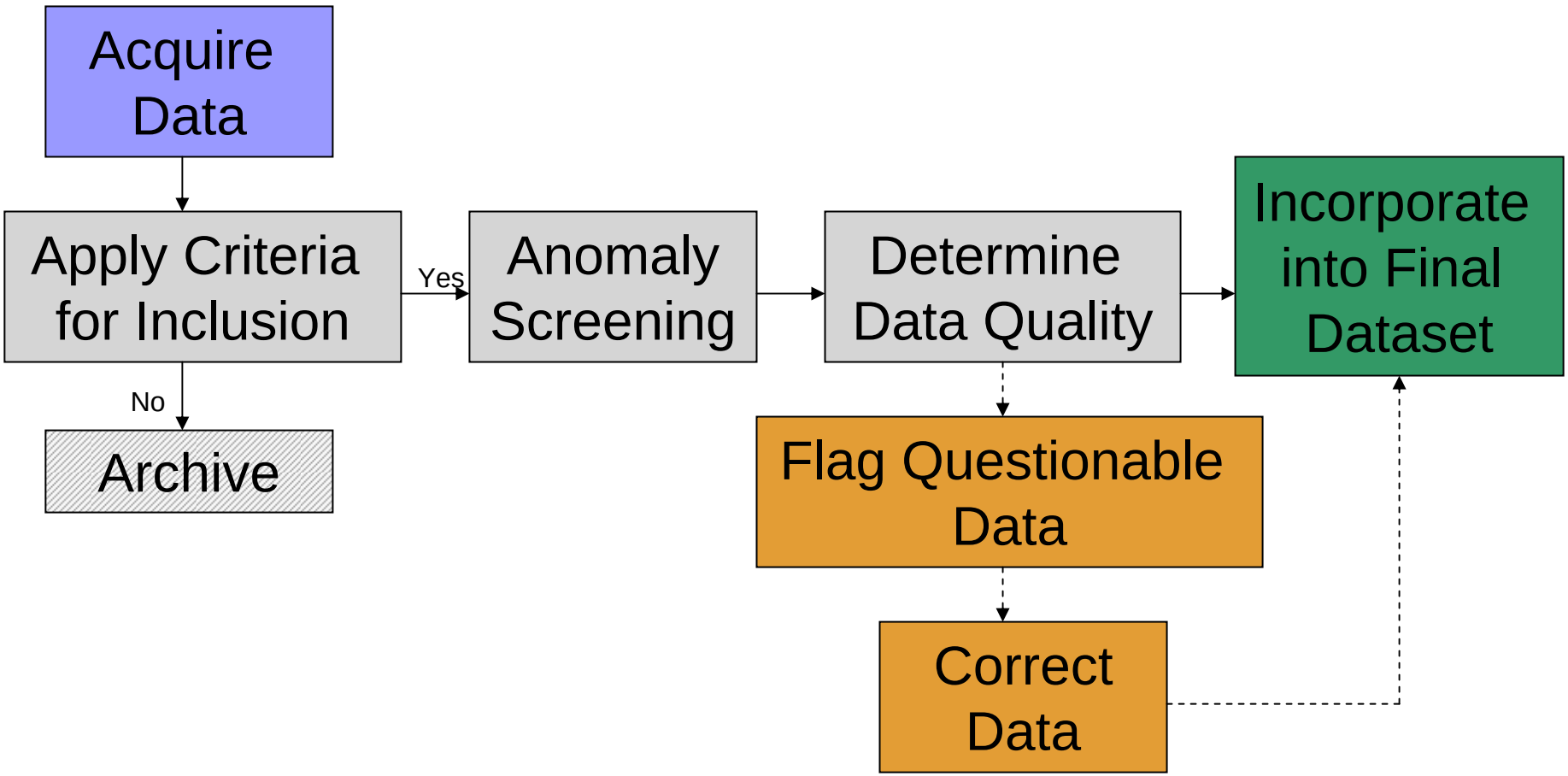
GMAQDB Datasets

- Special Studies Data:
  - MMS 1993 Gulf of Mexico Air Quality Study (GMAQS) data
  - MMS/OOC Atmospheric Boundary Layer (ABL) data (1998-2001)
  - Breton Area Monitoring Program (BAMP) (2000–2001)
  - Emissions data for Gulf of Mexico (2000 and 2005 Gulfwide offshore emissions inventories)

GMAQDB Datasets (concluded)

- Routine Data:
  - AIRS/AQS ozone, PM10, PM2.5, speciated particulates, SO2, & CO for coastal TX, LA, MS, AL & FL
  - IMPROVE data for Breton & other coastal sites
  - SouthEastern Aerosol Research and CHaracterization (SEARCH) data for MS, AL & FL
  - NWS surface & upper-air meteorological data for coastal TX, LA, MS, AL & FL
  - Meteorological buoy data for the Gulf of Mexico

Overview of MMS Synthesis Database Preparation



GMAQDB Tool

- Oracle database includes > 280 million data points from more than 1,400 monitoring locations (~ 28 GB)
- GUI consists of menus, forms & reports developed with Microsoft Access 2003
- Emissions data features: Retrieve specific subsets of the data based on a variety of criteria (e.g., platform/non-platform, year, area, complex ID)
  - Export data to MS Excel files
  - Emissions data maps

GMAQDB Tool (concluded)

- Monitoring data features: Retrieve specific subsets of the data based on a variety of criteria (e.g., date range, location, parameter type)
  - Export data to MS Excel files
  - Plots and reports (preview on screen or print)
    - Data availability summary report
    - Statistics report (min, max, mean)
    - Diurnal plots
    - Time series (single & multiple parameter) plots
  - Monitoring location maps
- Users can load new monitoring data from routine datasets (e.g., AQS, IMPROVE & NCDC)

MMS

Gulf of Mexico Air Quality Database

Monitoring Data Products

Monitoring Location Maps

Emissions Data Products

Emissions Data Maps

Load Data

Data Sets

Version 276
31-Mar-2008

Database Version:
Oracle Server

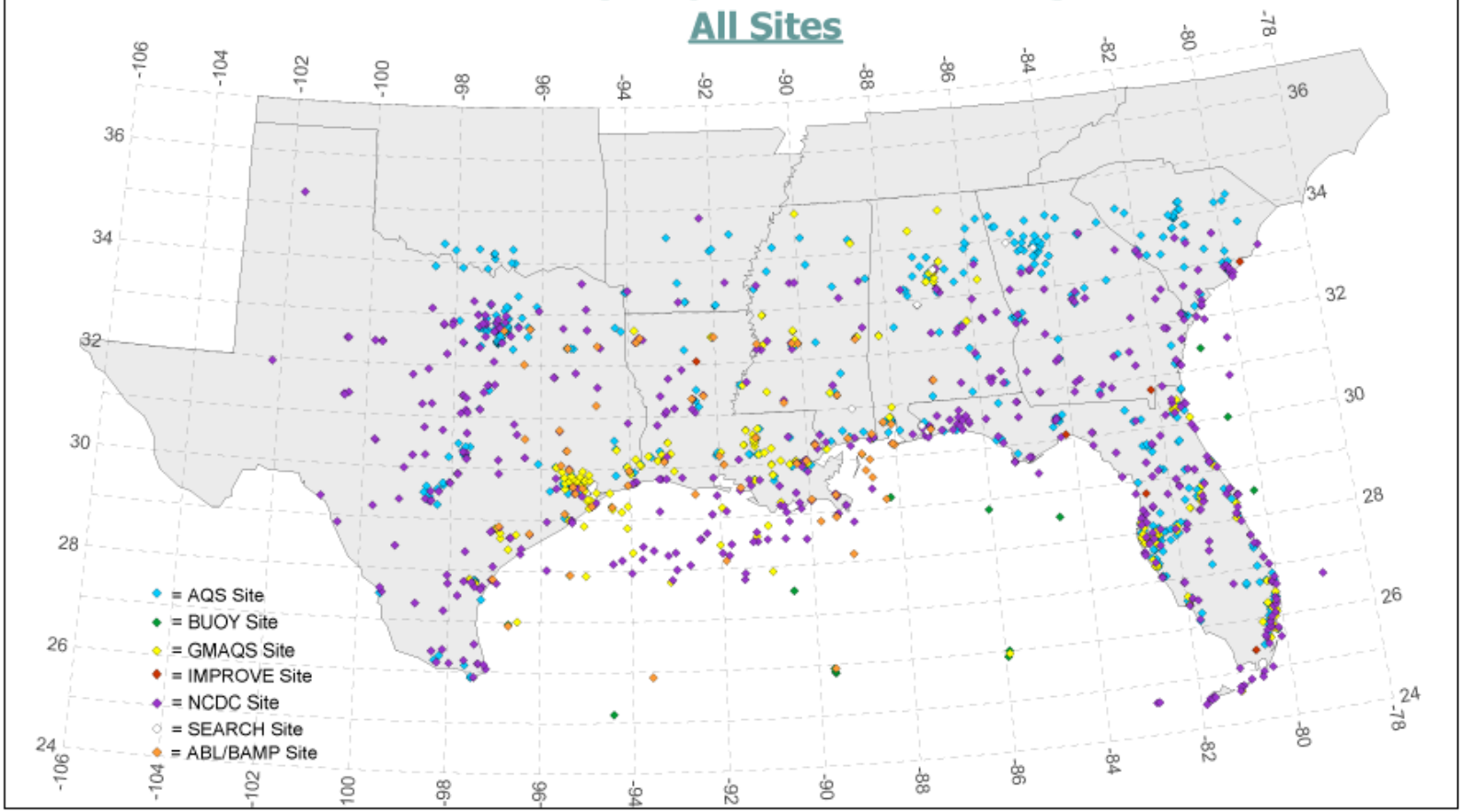
Print

GMAQDB Monitoring Locations Maps

close

Gulf of Mexico Air Quality Database Monitoring Locations

All Sites



Record: 1 of 8

GMAQDB Output Products

close

Select Product and Date Range | Select Parameters | Select Locations | Generate Output

Click the box to the left of an Item to select it.

Product Name	Product Description
☐ XLSOutput	Export selected records to a an Excel (XLS) - each selected location in a separate file
☐ XLSOutput	Export selected records to a an Excel (XLS) - all selected locations in one file.
☐ DataAvailability	Summary Report of Available Data/Percent Valid
☐ Diurnal	Diurnal plot
☐ Summary	Summary report of min,max, and mean
☐ Timeline	Timeline plot - single parameter
☐ MultiTimeLine	Timeline plot - multiple, pre-selected parameters
☐ XLSOutput	Upper Data - Export selected records to a an Excel (XLS) - each selected location in a separate

Enter the Date Range

Start Date: 7/1/2004

End Date: 7/31/2004

Jul 2004 — Jul — 2004

Sun	Mon	Tue	Wed	Thu	Fri	Sat
27	28	29	30	1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31
1	2	3	4	5	6	7

GMAQDB Output Products

close

Select Product and Date Range | Select Parameters | Select Locations | Generate Output

Parameter Type

All

- All
- Gaseous
- Meteorology
- Misc
- Speciated PM
- Total PM
- Visibility

☐ Select/Deselect all displayed Parameters ☑ List only the Parameters for the selected Date Range

		Parameter Description	Standard Units	AQS Parameter Code
	logy	Altimeter Setting	inches	
		Average Wave Period	sec	
	ed PM	Chlorine (fine)	ug/m3 lc	88115
		Carbon Monoxide	ppm	42101
☐ DPD	Misc	Dominant Wave Period	sec	
☐ DV	Visibility	Deciview	none	
☐ ECf_TOR	Speciated PM	Elemental Carbon (fine) - TOR Method	ug/m3 lc	
☐ ECf_TOT	Speciated PM	Elemental Carbon (fine) - TOT Method	ug/m3 lc	88307
☐ ECf_bext	Visibility	Elemental Carbon Extinction (fine)	Mm-1	
☐ HNO3	Gaseous	Nitric Acid	ppm	
☐ MMOc	Speciated PM	Soil (Fine) - SEARCH Method	ug/m3 lc	
☐ MMOf	Speciated PM	Soil (Coarse) - SEARCH Method	ug/m3 lc	
☐ MWD	Misc	Mean Wave Direction	degrees	
☐ NH4c	Speciated PM	Ammonium (coarse)	ug/m3 lc	
☐ NH4f	Speciated PM	Ammonium (fine)	ug/m3 lc	88301
☐ NO	Gaseous	Nitric Oxide	ppm	42601
☐ NO2	Gaseous	Nitrogen Dioxide	ppm	42602
☐ NO3c	Speciated PM	Nitrate (coarse)	ug/m3 lc	
☐ NO3f	Speciated PM	Nitrate (fine)	ug/m3 lc	88306
☐ NO3f_Non	Speciated PM	Nitrate (non-volatile, fine)	ug/m3 lc	88310
☐ NO3f_Vol	Speciated PM	Nitrate (volatile, fine)	ug/m3 lc	88309
☐ NOX	Gaseous	Oxides Of Nitrogen	ppm	42603
☐ NOY	Gaseous	Reactive Oxides Of Nitrogen	ppm	42600
☐ O3	Gaseous	Ozone	ppb	44201
☐ OCf_TOT	Speciated PM	Organic Carbon (fine) - TOT Method	ug/m3 lc	88305
☐ OMCf	Speciated PM	Organic Mass (fine)	ug/m3 lc	
☐ OMCf_bext	Visibility	Organic Mass Extinction (fine)	Mm-1	
☐ P	Meteorology	Barometric Pressure	mb	64101
☐ PM10	Total PM	PM10	ug/m3 25c	81102
☐ PM2.5	Total PM	PM2.5	ug/m3 lc	88101
☐ PMC	Speciated PM	Coarse Mass	ug/m3 lc	
☐ PMC_bext	Visibility	Coarse Mass Extinction	Mm-1	

GMAQDB Output Products

close

Select Product and Date Range | Select Parameters | Select Locations | Generate Output

Sort Options

Sort by Location ID

Filter Options

- [x] Display only Locations with Data for the Selected Date Range
- [x] Filter by Data Set
- [ ] Select/deselect all displayed locations

Filter By Latitude/Longitude Boundaries

- [ ] Enter as degrees, minutes, seconds

	Minimum			Maximum		
Latitude:	24.46			35.23		
Longitude:	-79.00			-102.20		

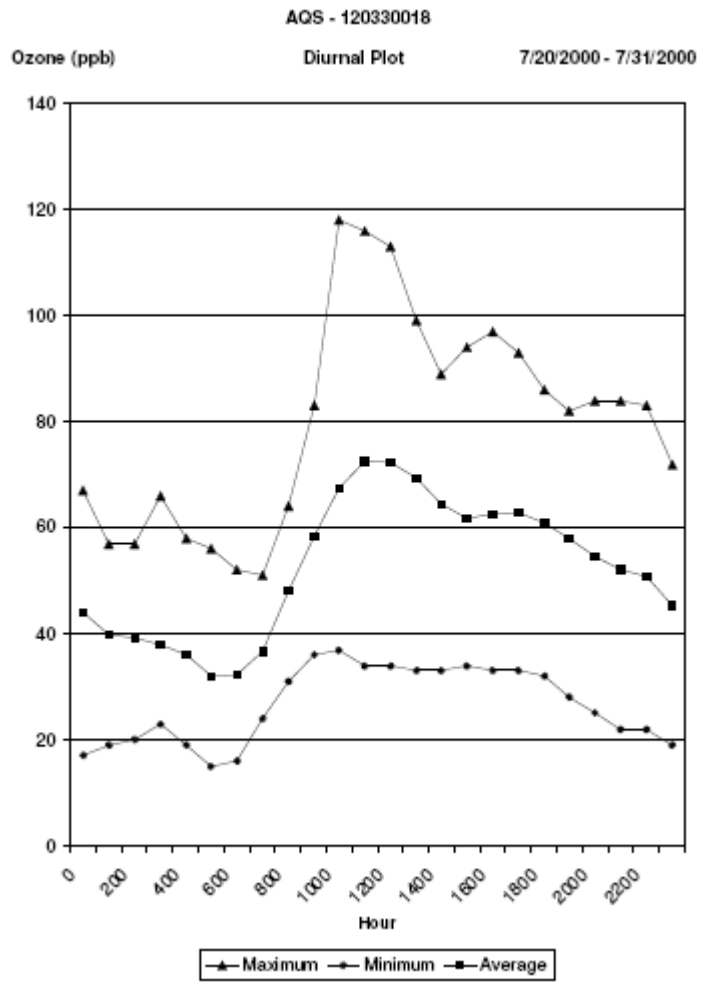
Display Locations within Boundaries

Data Set

ABL_BAMP	Breton Island Aerometric Monitoring Program
AQS	EPA AQS
BUOY	National Oceanic and Atmospheric Administration's National Data Buoy Center
GMAQS	Gulf of Mexico Air Quality Study
IMPROVE	Interagency Monitoring of Protected Visual Environments
NCDC	National Climatic Data Center Surface Met Data and Upper Air Met Data
SEARCH	Southeastern Aerosol Research and Characterization Study

				Lat (deg)	Lon (deg)	Elev (n
				30.497778	87.881389	37.1
				33.281111	85.802222	344.4
				34.2875	85.968333	50
			E CO., AL	32.498333	86.136667	53.9
010530002	AQS	AL	BELLVILLE AVE.BREWTON, ESCAMBIA CO., AL	31.106389	87.071111	5
010550008	AQS	AL	3200 WALNUT ST, ETOWAH CO., AL	34.015	86.012222	
010550010	AQS	AL	1001 WALLACE DRIVE, GADSDEN, AL 35902, ETOWAH CO., AL	33.993611	85.991111	5
010550011	AQS	AL	1450 PARKER ANDERSON LANE, SOUTHSIDE, AL 35907, ETOWAH CO., AL	33.9039	86.0539	152.
010690002	AQS	AL	EAST HIGHLAND ST., BOARD OF ED. BLDG., HOUSTON CO., AL	31.228611	85.375556	10
010730002	AQS	AL	1500 1ST AVE N., BESSEMER, AL, JEFFERSON CO., AL	33.3975	86.955278	16
010730023	AQS	AL	NO. B'HAM,SOU R.R., 3009 28TH ST. NO., JEFFERSON CO., AL	33.553056	86.815	17
010730028	AQS	AL	EAST THOMAS, FINLEY, 841 FINLEY AVE. BP., JEFFERSON CO., AL	33.529444	86.850278	16
010730034	AQS	AL	2301 11TH AVE NORTH, BIRMINGHAM, JEFFERSON CO., AL	33.5275	86.807778	18
010731003	AQS	AL	FAIRFIELD, PFD, 5229 COURT B, JEFFERSON CO., AL	33.485556	86.915	18
010731005	AQS	AL	ROUTE 8 MCADORY, JEFFERSON CO., AL	33.331111	87.003611	16
010731008	AQS	AL	3822 WILLIAMSON DRIVE, JEFFERSON CO., AL	33.451389	86.967222	16
010731009	AQS	AL	1801 BRUCE SHAW ROAD, JEFFERSON CO., AL	33.459722	87.305556	22
010731010	AQS	AL	201 ASHVILLE ROAD, JEFFERSON CO., AL	33.545278	86.549167	19
010732003	AQS	AL	1242 JERSEY ST WYLAM AL, JEFFERSON CO., AL	33.499722	86.924167	19
010732006	AQS	AL	3425 TAMASSEE LANE, HOOVER, AL 35226, JEFFERSON CO., AL	33.386389	86.816667	18
010735002	AQS	AL	PINSON, HIGH SCH., BOX 360 HWY 75 NORTH, JEFFERSON CO., AL	33.704722	86.669167	20
010735003	AQS	AL	10005 CORNER SCHOOL ROAD, JEFFERSON CO., AL	33.801667	86.9425	21
010736002	AQS	AL	TARRANT, ELEM. SCH., 1269 PORTLAND STREE, JEFFERSON CO., AL	33.578333	86.773889	17
010736004	AQS	AL	4113 SHUTTLESWORTH DRIVE, JEFFERSON CO., AL	33.565278	86.796389	17

Example GMAQDB Analysis Products



Pensacola

GMAQDB Data Availability

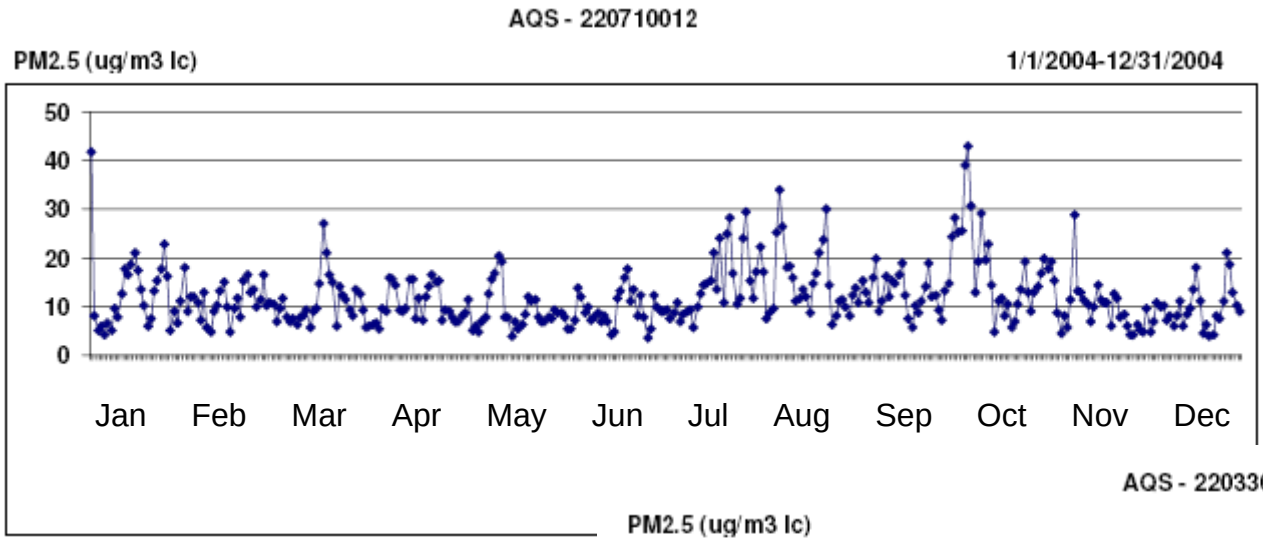
Site: BUOY - 42035

Selected Date Range: 1/1/2004 - 12/31/2004

Parameter	Valid Observations		
	Begin Date Time	End Date Time	No.
WS - Wind Speed	01/01/04 00:00	12/31/04 16:00	8675
WD - Wind Direction	01/01/04 00:00	12/31/04 16:00	8675
T - Temperature	01/01/04 00:00	12/31/04 16:00	8656
SST - Sea Surface Temperature	01/01/04 00:00	12/31/04 16:00	8647

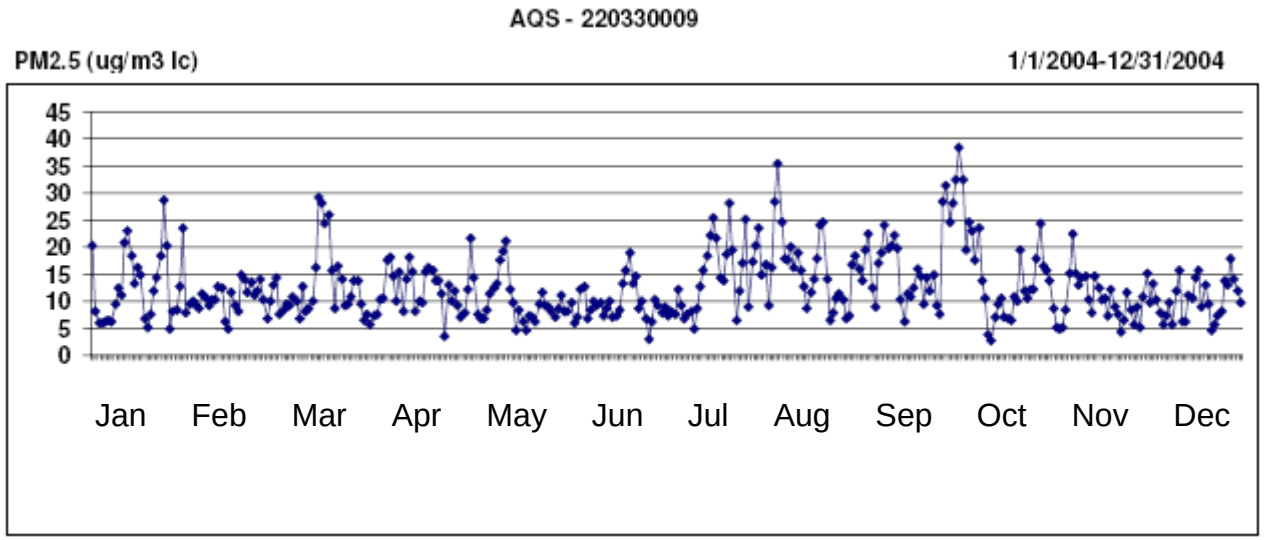
Buoy 42035

Example GMAQDB Analysis Products

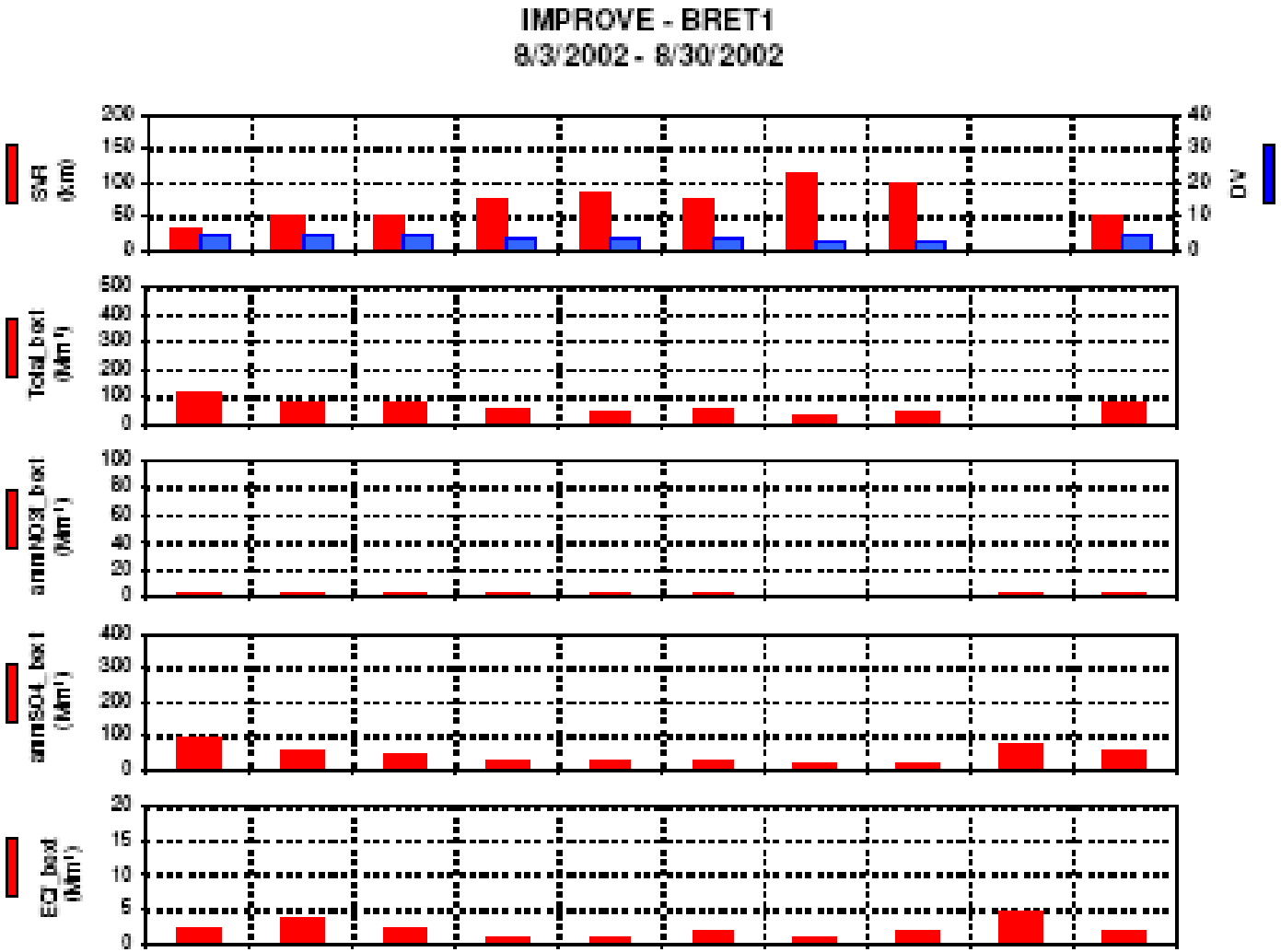


New Orleans

Baton Rouge

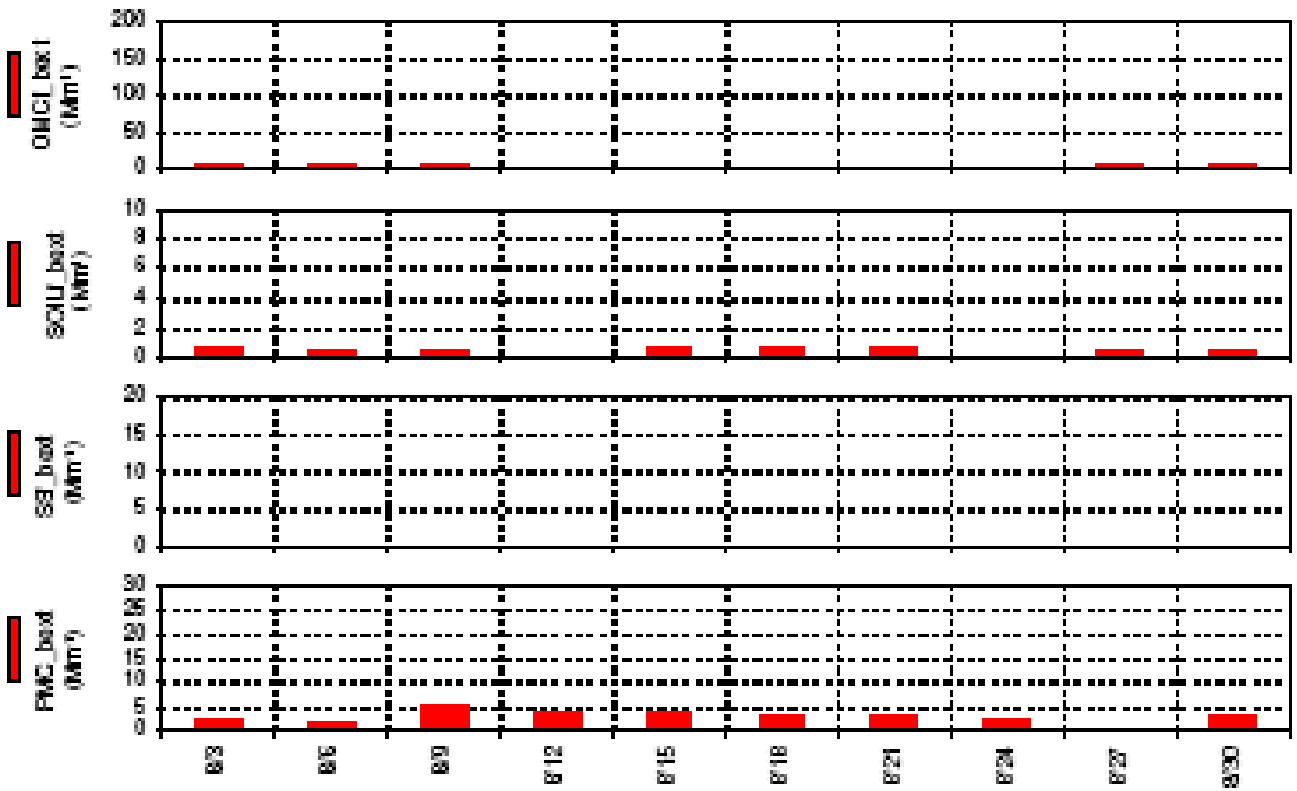


Example GMAQDB Analysis Products



Breton NWA

Example GMAQDB Analysis Products



Breton NWA

GMAQDB Emissions Data Output Products

close

Select Output Product and Year | Select Pollutants | Select Sources | Generate Output

Select Source Type

All

Select Areas

By Area Code

Area Code	Description
AC	Minos Canyon
AM	Amery Terrace
AT	Atwater
BA	Brazos Area
BM	Bay Marchand Area
BS	Breton Sound Area
CA	Chandeleur Area
CC	Corpus Christi
EB	East Breaks
EC	East Cameron Area
EI	Eugene Island Area
FW	Ewing Bank

By Latitude/Longitude Boundaries

Enter as Degrees, Minutes, Seconds

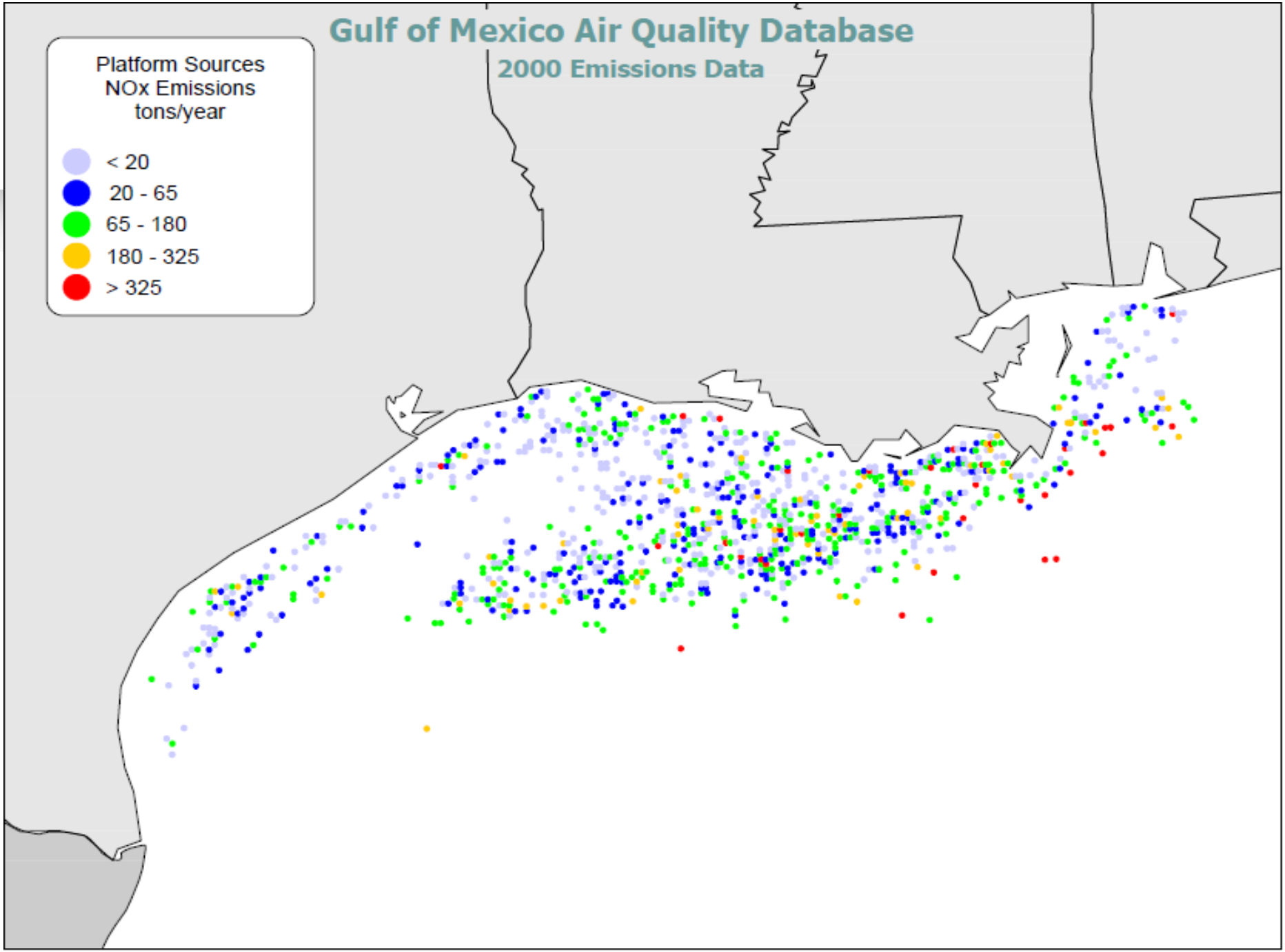
	Minimum	Maximum
Latitude:	25.59	30.17
Longitude:	-97.11	-87.75

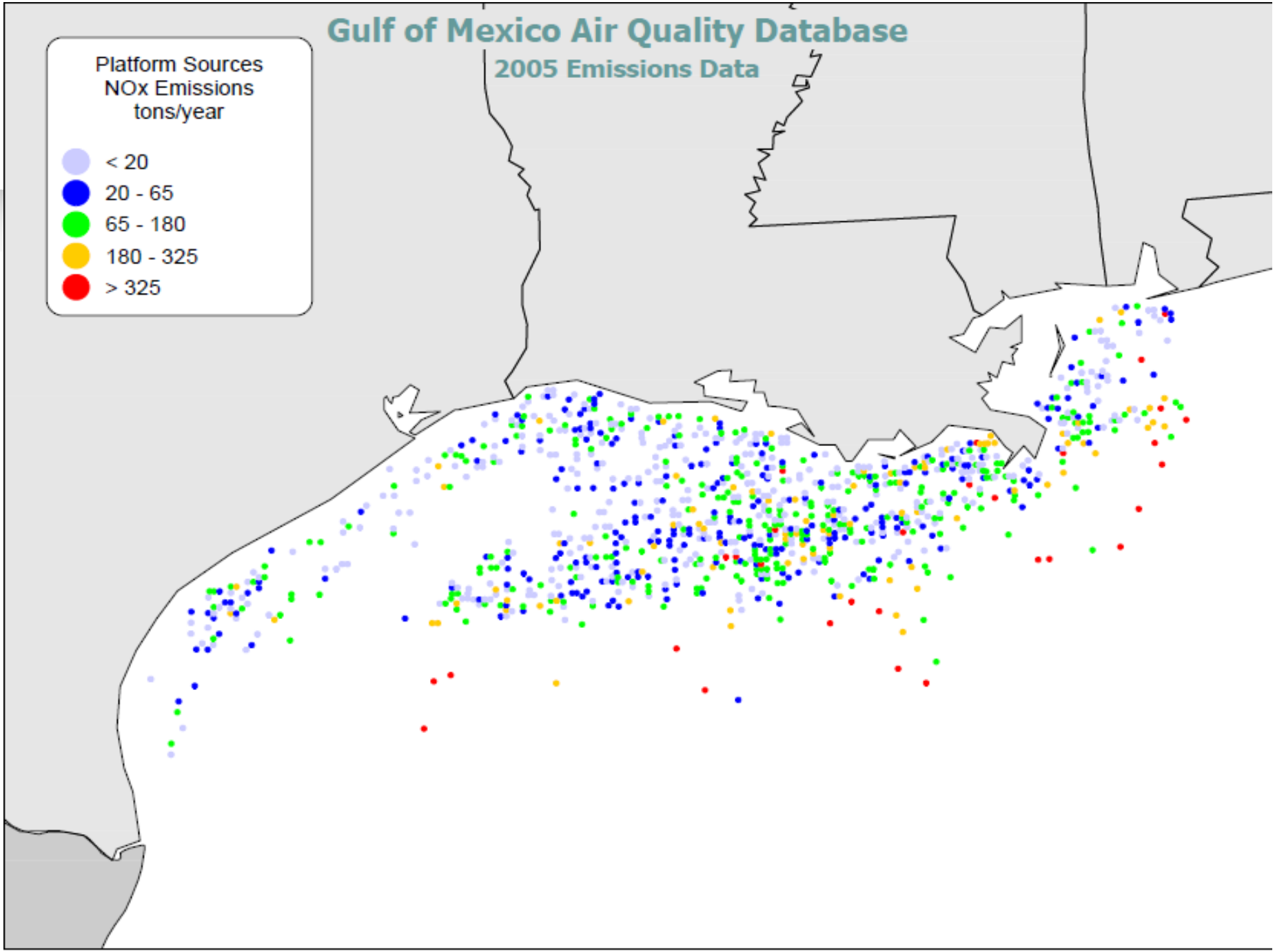
Select Complex ID Numbers

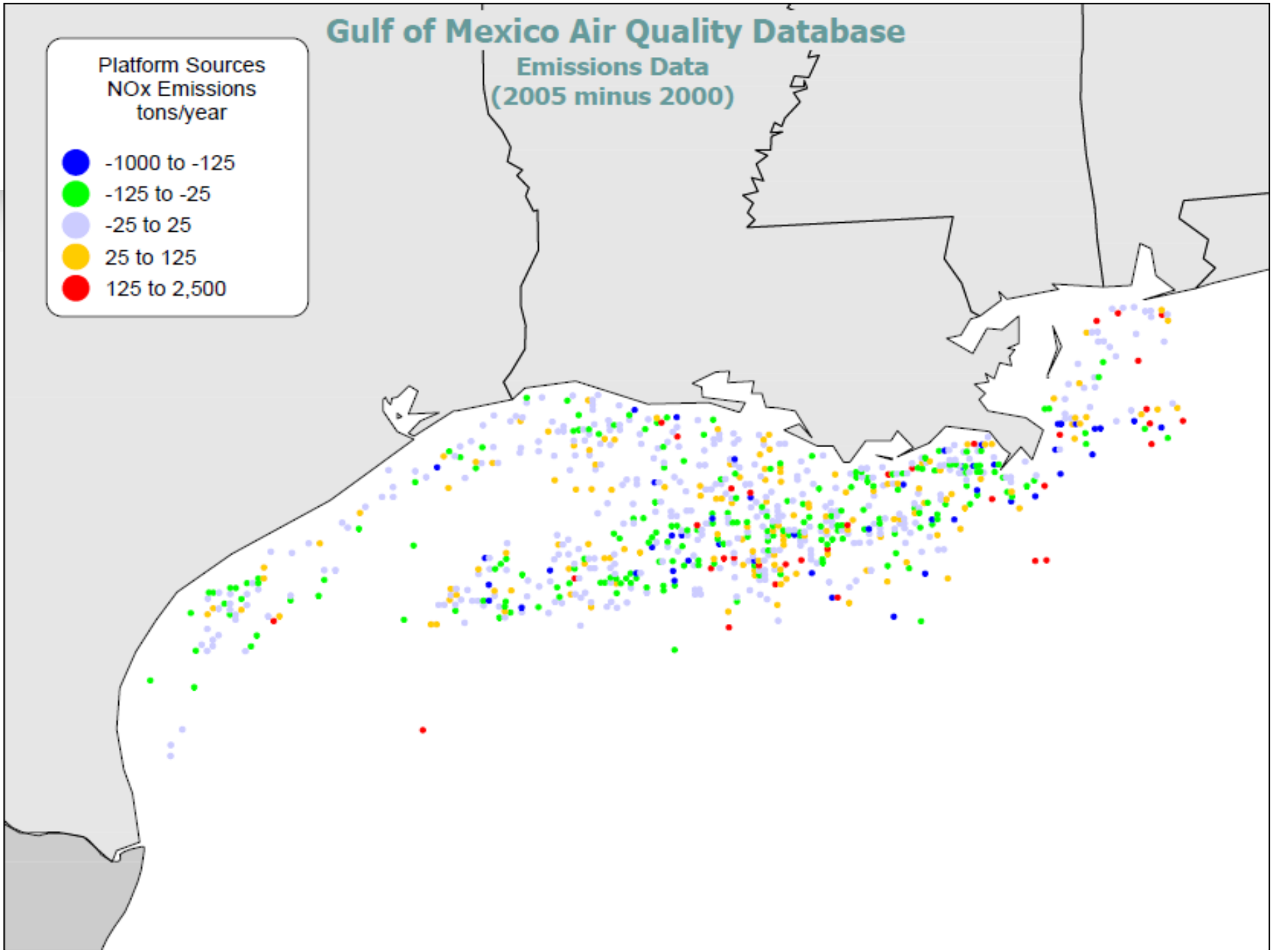
Complex ID	Company Name
100	Unocal
10003	ENERGY RESOURCE TECH...
10003	Sterling Energy, Inc.
10006	Shell Offshore Inc.
10007	Shell Offshore Inc.
1001	BP Exploration & Production Inc.
10011	Devon Energy Corp.
10012	Devon Energy Corp.
10012	Nippon Oil Exploration U.S.A. ...
10015	Shell Offshore Inc.
10023	Bellwether Exploration Company
10028	Shell Offshore Inc.
10031	ConocoPhillips Company
10031	Shell Offshore Inc.
10039	W & T Offshore, Inc.
10039	W&T Offshore, Inc.
10050	Coastal Oil & Gas

Select NonPlatform Names/SCC

NonPlatformName	SCC Code	SCC Description
Bio/Geogenic	2740040000	Natural Sources: Misc
CMV	2280002200	Mobile Sources; Commercial Marine Vessels: Diesel: Underway
CMV_steam	2280003200	Mobile Sources; Commercial Marine Vessels: Residual: Underway
DrillingRigs	2280002200	Mobile Sources; Commercial Marine Vessels: Diesel: Underway
Fishing	2280002200	Mobile Sources; Commercial Marine Vessels: Diesel: Underway
Helicopters	2275050000	Mobile Sources;Aircraft;General Aviation;Total
LOOP	2280002200	Mobile Sources; Commercial Marine Vessels: Diesel: Underway
LOOP_Approach	2280002200	Mobile Sources; Commercial Marine Vessels: Diesel: Underway
LOOP_CMV_Platform	2280002200	Mobile Sources; Commercial Marine Vessels: Diesel: Underway
LOOP_Platform	2020010200	Combustion engine Diesel
Lightering	2275050000	Mobile Sources;Aircraft;General Aviation;Total
Lightering	2280002200	Mobile Sources; Commercial Marine Vessels: Diesel: Underway
MilitaryVessels	2280002200	Mobile Sources; Commercial Marine Vessels: Diesel: Underway
Pipelaying	2280002200	Mobile Sources; Commercial Marine Vessels: Diesel: Underway
PlatformConstRemove	2280002200	Mobile Sources; Commercial Marine Vessels: Diesel: Underway
SupportVessels	2280002200	Mobile Sources; Commercial Marine Vessels: Diesel: Underway
SurveilVessels	2280002200	Mobile Sources; Commercial Marine Vessels: Diesel: Underway


Gulf of Mexico Air Quality Database
2000 Emissions Data
Platform Sources
NOx Emissions
tons/year
< 20
20 - 65
65 - 180
180 - 325
> 325


Gulf of Mexico Air Quality Database
2005 Emissions Data
Platform Sources
NOx Emissions
tons/year
< 20
20 - 65
65 - 180
180 - 325
> 325


Gulf of Mexico Air Quality Database
Emissions Data
(2005 minus 2000)
Platform Sources
NOx Emissions
tons/year
-1000 to -125
-125 to -25
-25 to 25
25 to 125
125 to 2,500

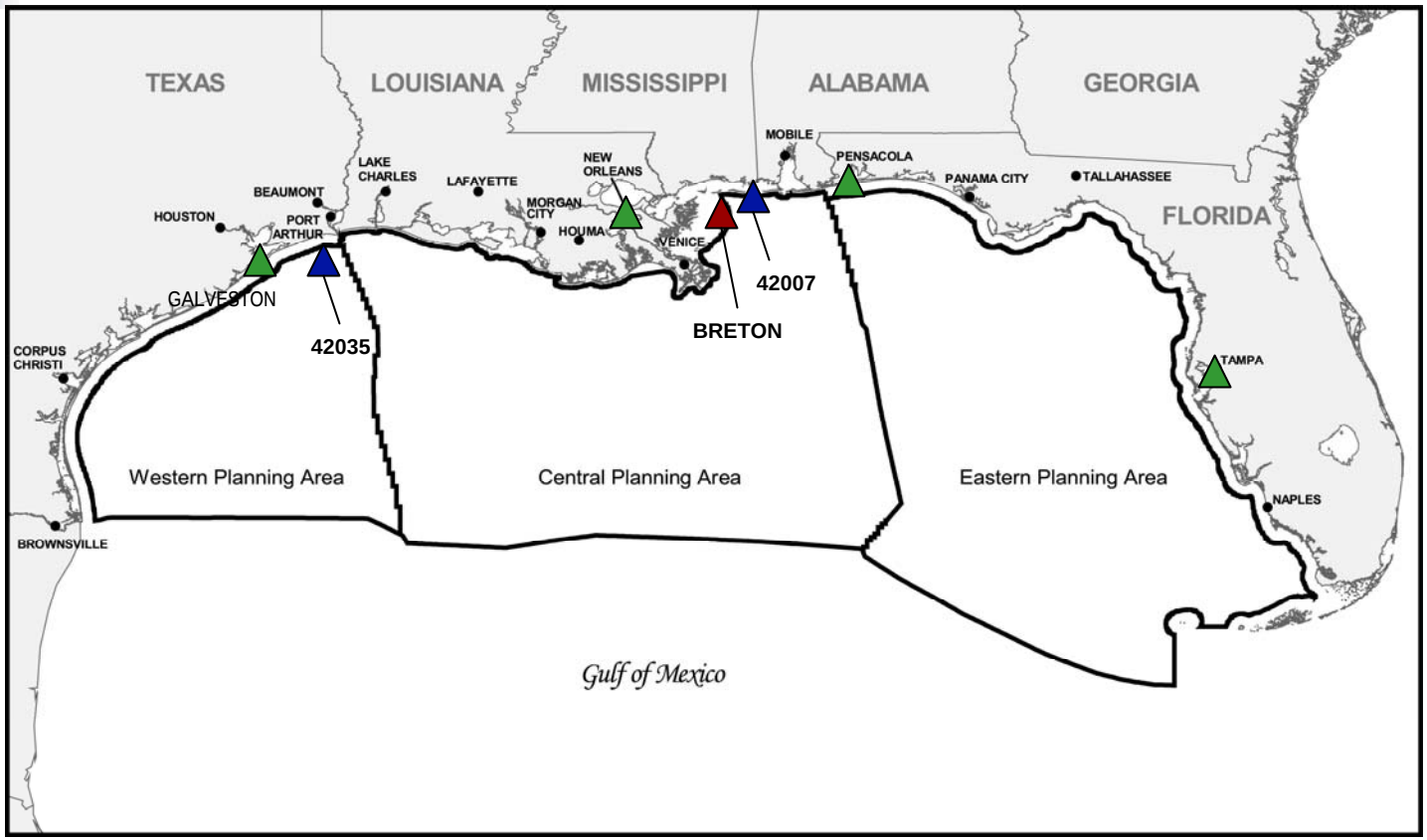
Data Analyses

- Data summaries
  - Statistical and graphical overview of the meteorological & air quality data
- CART analysis for the Breton NWA
  - Classification and Regression Tree (CART) analysis to probe the relationships between meteorology, PM2.5 and visibility (regional haze)
- CART analysis for coastal ozone non-attainment areas
  - Examination of the relationships between onshore and offshore meteorological conditions and ozone air quality in coastal non-attainment areas

Data Analyses (concluded)

- Air quality trends analysis
  - Information on the effects of meteorology & emissions changes on onshore 8-hour ozone and PM2.5 air quality
- Case study analyses (MM5 evaluation)
  - Comparison of existing MM5 results with the special studies meteorological data

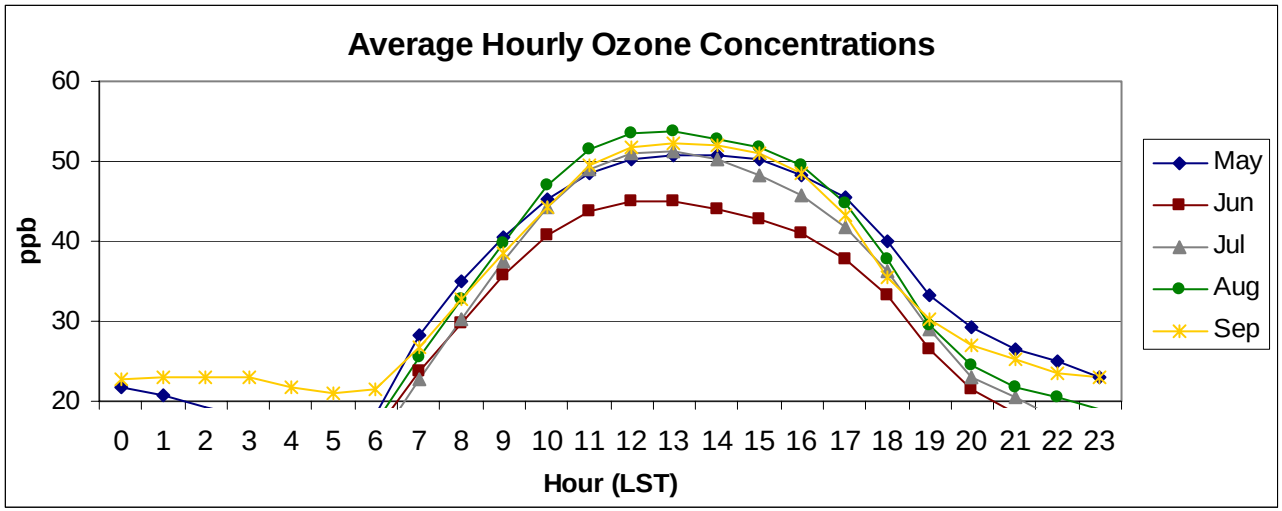
Monitoring Sites Highlighted in Today's Presentation



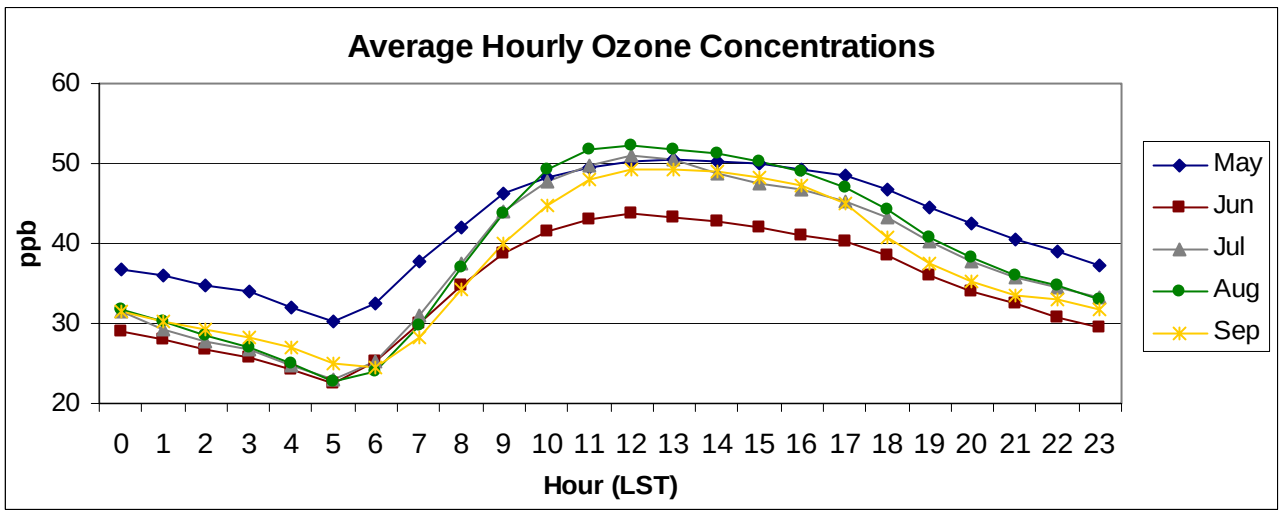
▲ = Ozone, PM2.5 and sfc met ▲ = Visibility ▲ = Buoy (met)

Monthly Average Diurnal Profile for Ozone

Typical Profile for Urban Sites (New Orleans)

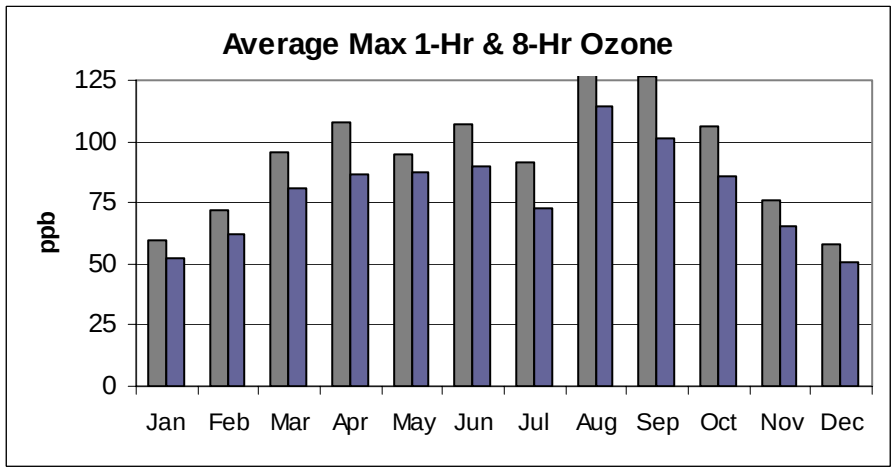


Typical Profile for Coastal Sites (Pensacola)

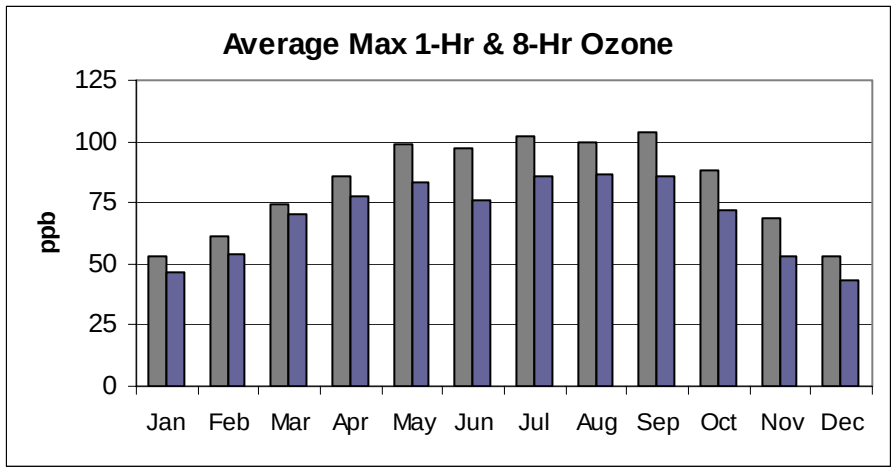


Annual Variations in 1-Hr & 8-Hr Ozone for 4 Different Areas

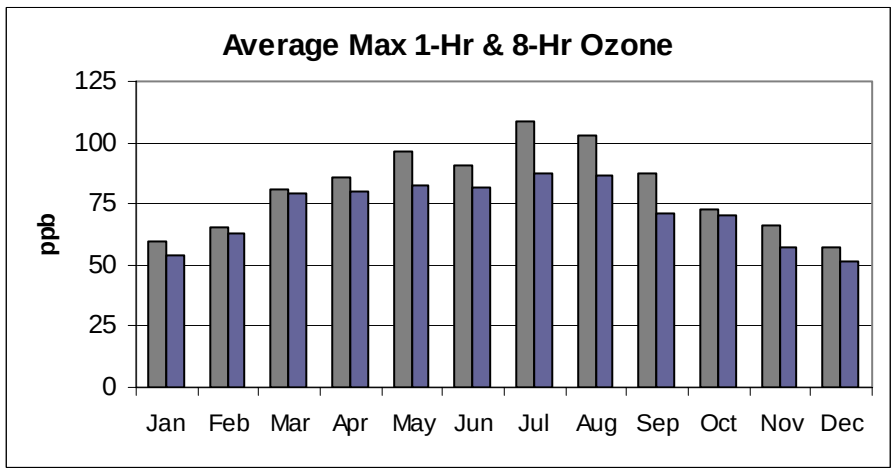
Galveston



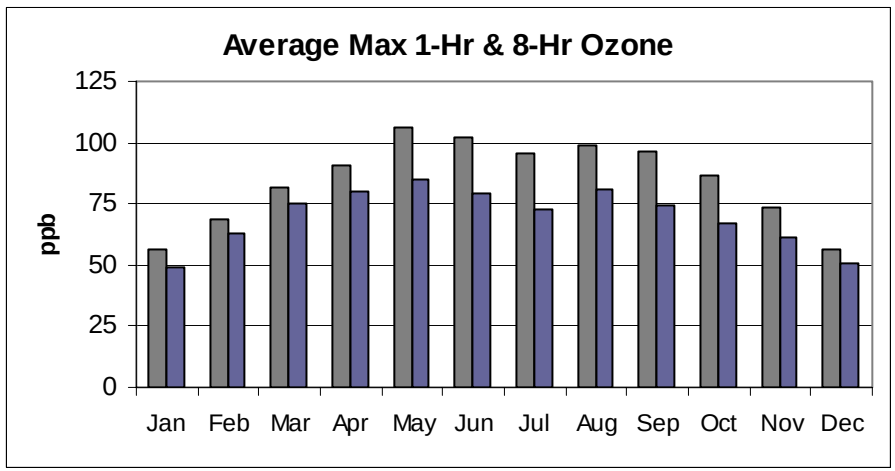
New Orleans



Pensacola

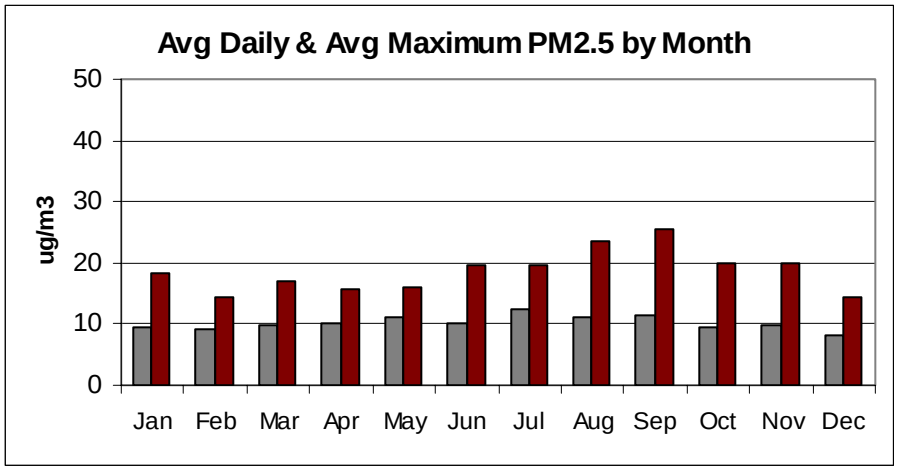


Tampa

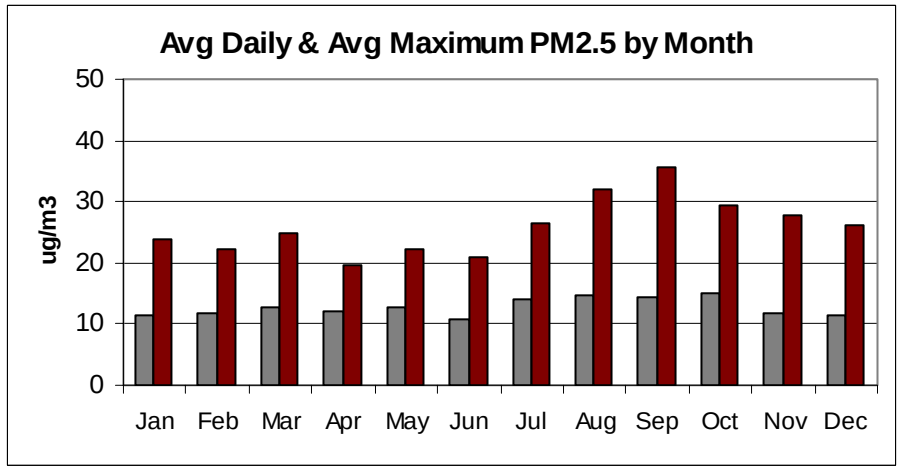


Annual Variations in PM2.5 for 4 Different Areas

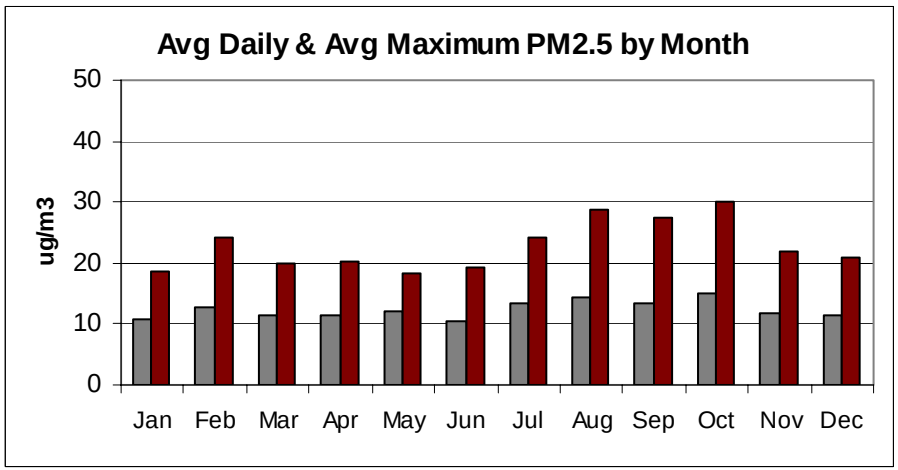
Galveston



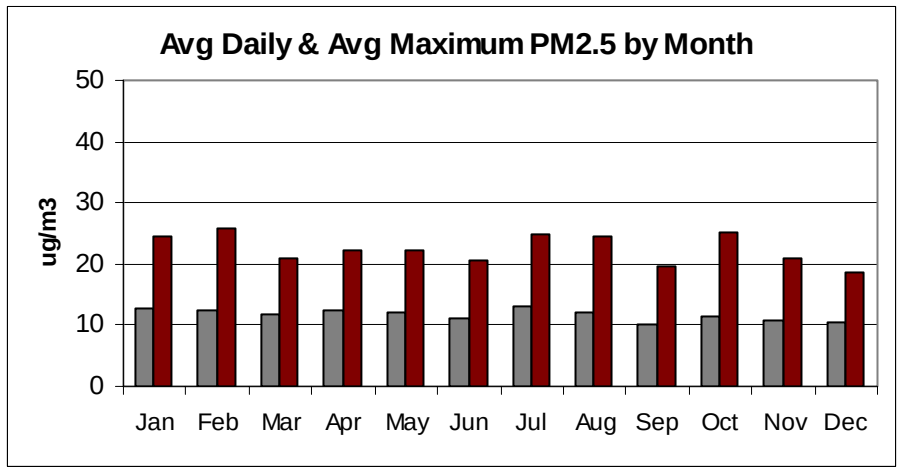
New Orleans



Pensacola

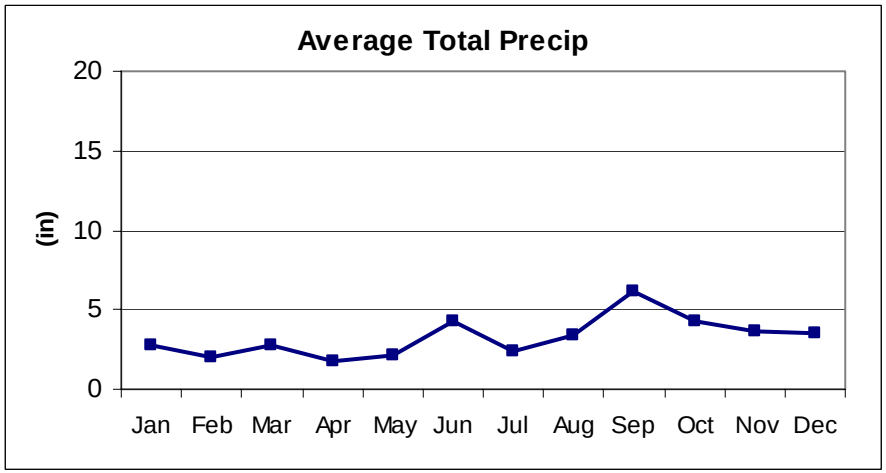


Tampa

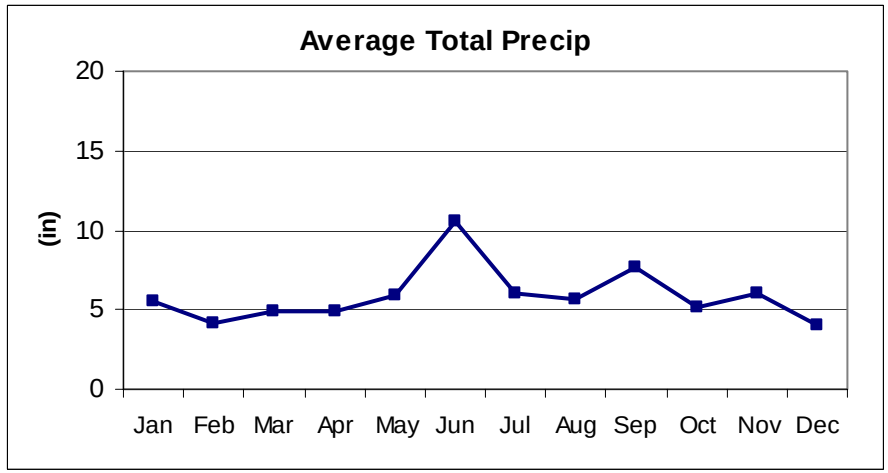


Average Monthly Rainfall Totals

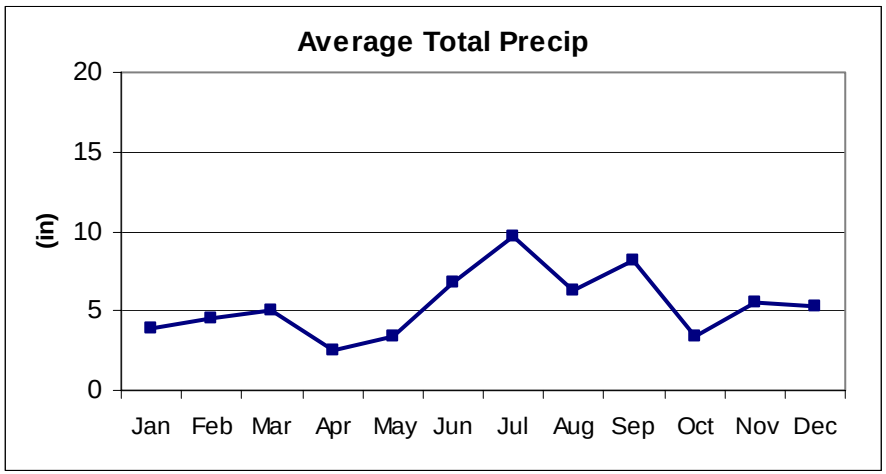
Galveston



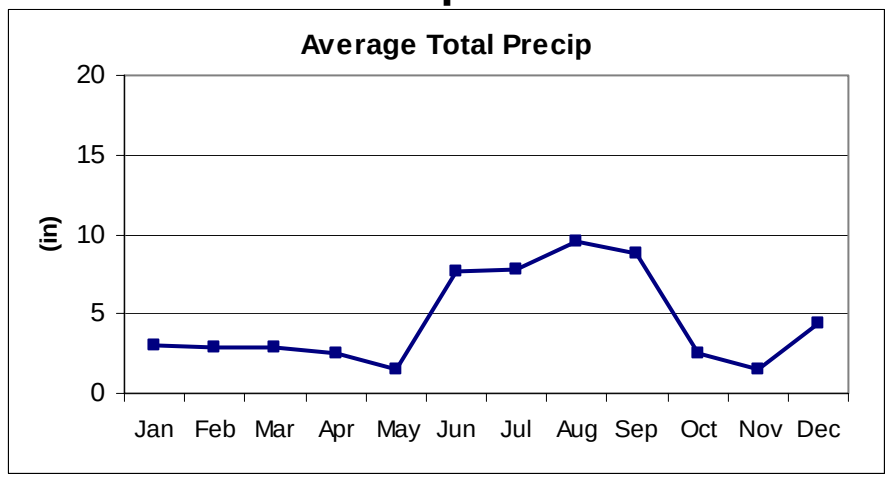
New Orleans



Pensacola

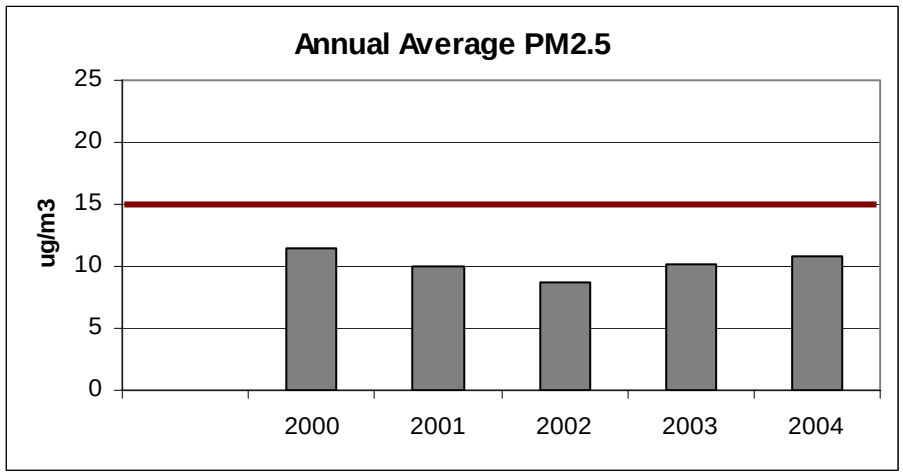


Tampa

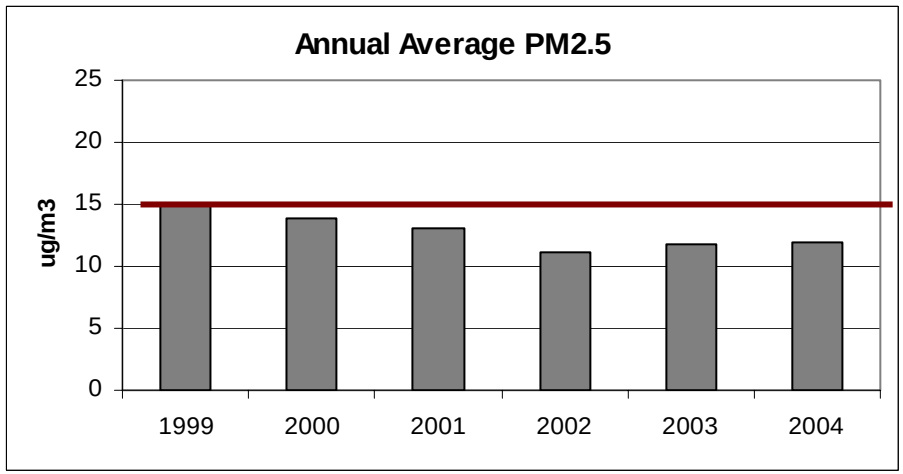


Annual Average PM2.5

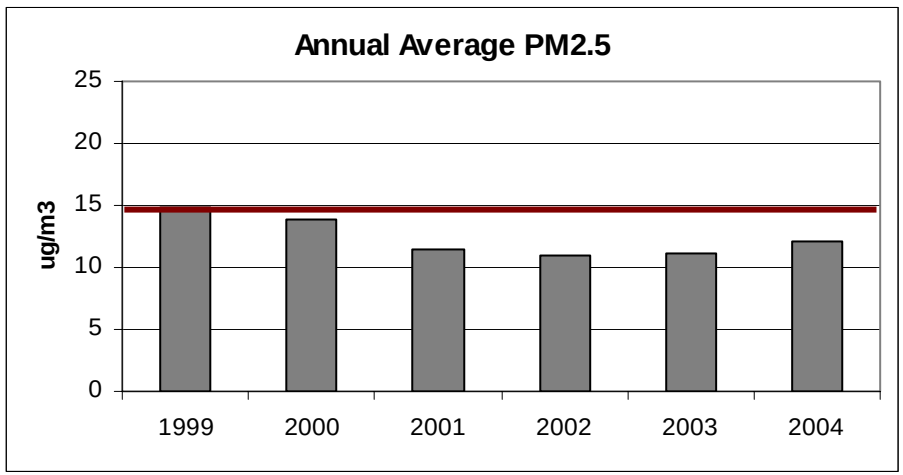
Galveston



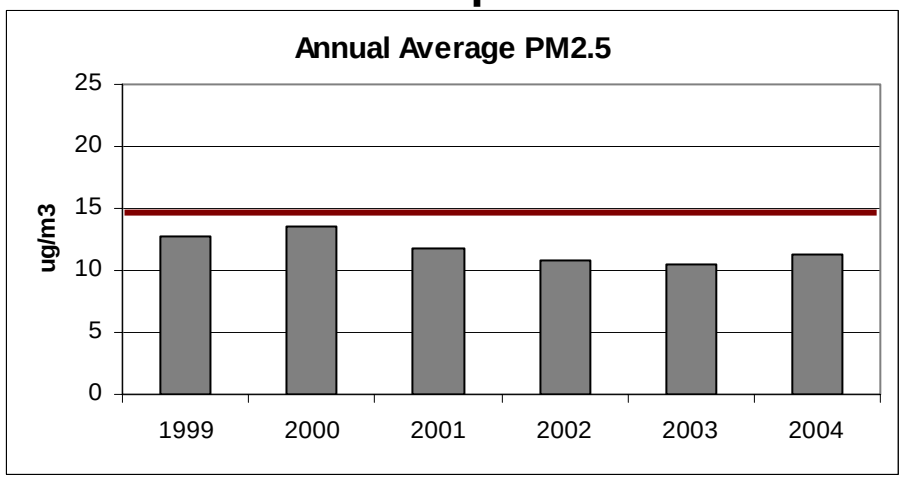
New Orleans



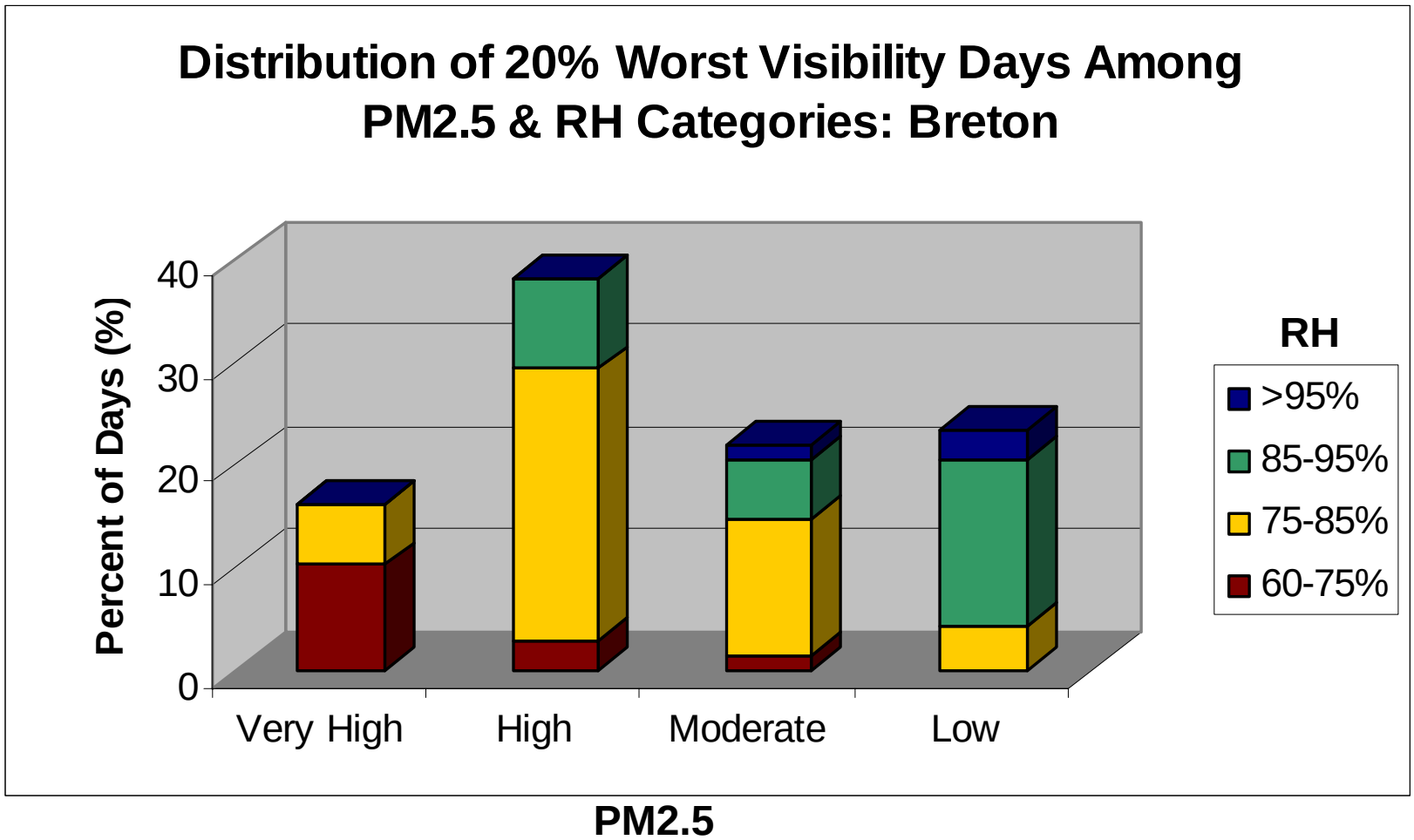
Pensacola



Tampa



Visibility, PM2.5 & Relative Humidity: Breton NWA



Example Findings from Data Summaries

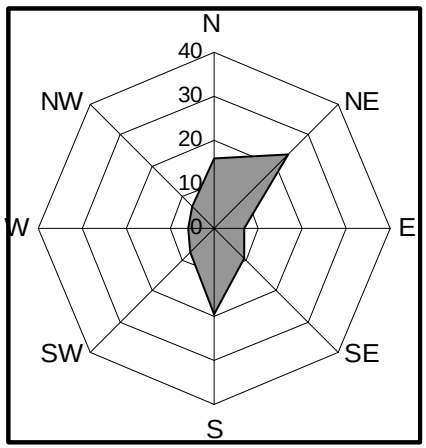
- Considering regulatory standards, the key air quality issue is ozone (many areas have design values above the current 8-hour ozone standard)
- Air quality metrics have some features that are characteristic of the GOM region (e.g., seasonal & diurnal ozone profiles) or common for the southern U.S. (e.g., PM2.5 predominantly SO4)

Example Findings from Data Summaries (concluded)

- Air quality values vary among the selected areas (due to difference in emissions and other geographical/ meteorological factors)
- Data suggest that the relationship between ozone, PM2.5 or visibility is rather complex (no single meteorological parameter or group of parameters easily defines this relationship)

Ozone & Wind Distributions (Ozone Season): New Orleans

Surface Winds



Calm = 3%

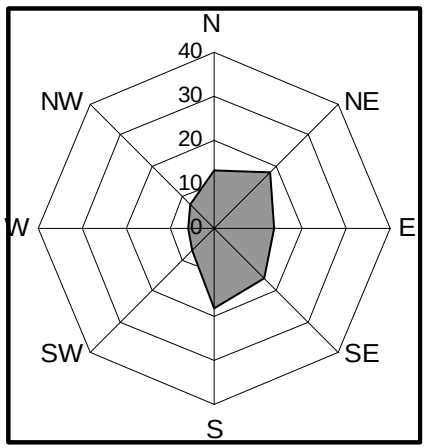
WD → / WS (m/s)	N	NE	E	SE	S	SW	W	NW
<1	60							
1-2	72	78	53	67	80	53	58	56
2-3	74	79	56	42	55	52	82	63
3-4	69	72	42	49	52	58	63	82
4-5	69	70	70	56	53	54	73	72
5-6	62	69	53	61	46	44	67	80
6-7	58	63	51	58	46	48	60	50
7-8	54	56		40	46	31	24	55
8-9	45			64	44		68	51
9-10	47				50			
>=10		27			48			

80th %tile daily maximum 8-hour ozone (ppb)

Highest values ~ low wind speeds;
W to NW wind directions

PM2.5 & Wind Distributions (Annual): New Orleans

Surface Winds



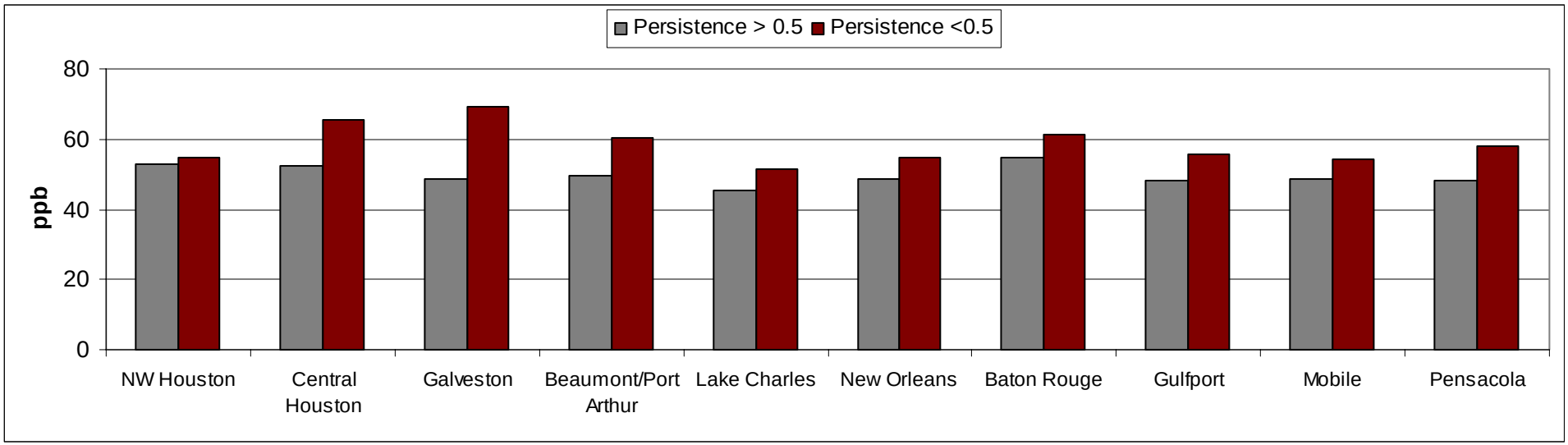
Calm = 0%

WD → / WS (m/s)	N	NE	E	SE	S	SW	W	NW
<1	19							
1-2	25	28	21	22	15	14	18	21
2-3	21	22	20	17	16	17	22	17
3-4	21	19	17	16	13	15	19	19
4-5	15	16	14	15	11	16	24	15
5-6	13	13	12	11	15	13	12	11
6-7	10	11	12	11	11	7	11	9
7-8	8	12		13	13	7	7	10
8-9	7					7	5	6
9-10	6	2		5				
>=10	9							

80th %tile 24-hr average PM2.5 (μg/m3)

Highest values ~ low wind speeds; N to E wind directions

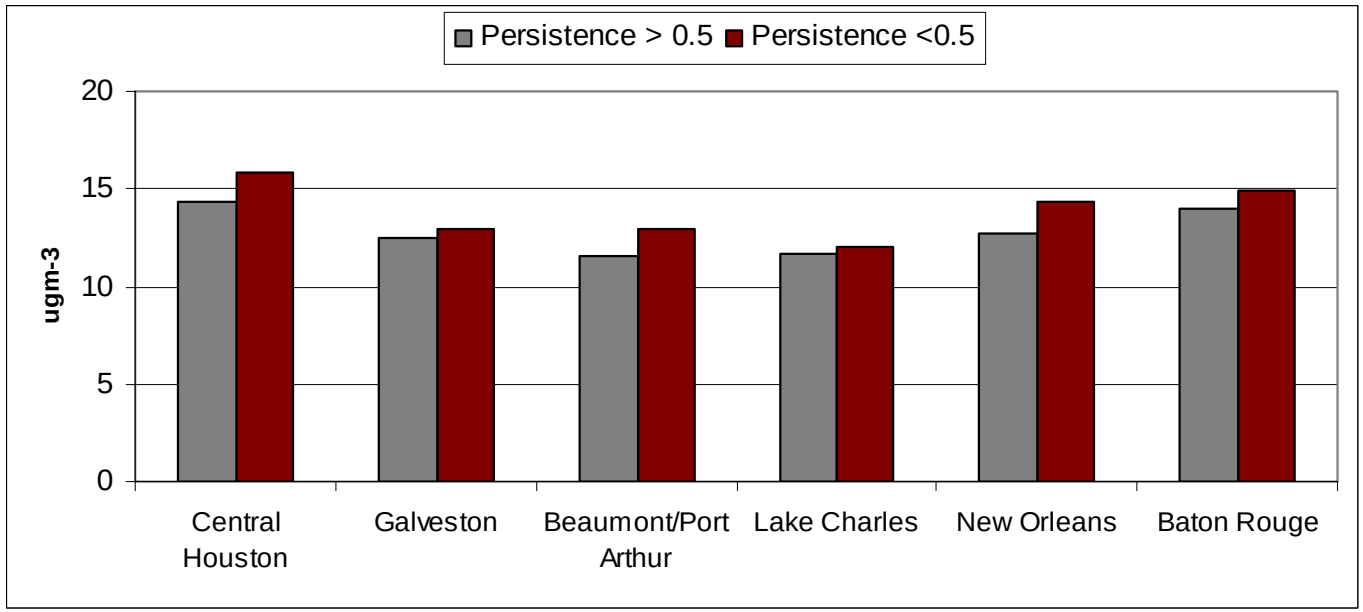
Effect of Recirculation (Possible Gulf Breeze) on Ozone



Persistence = index of recirculation = $\overline{\mathbf{u}} / |\overline{u}|$

Maximum 8-hour ozone: 2 to 20 ppb greater for days with recirculation (possible gulf breeze)

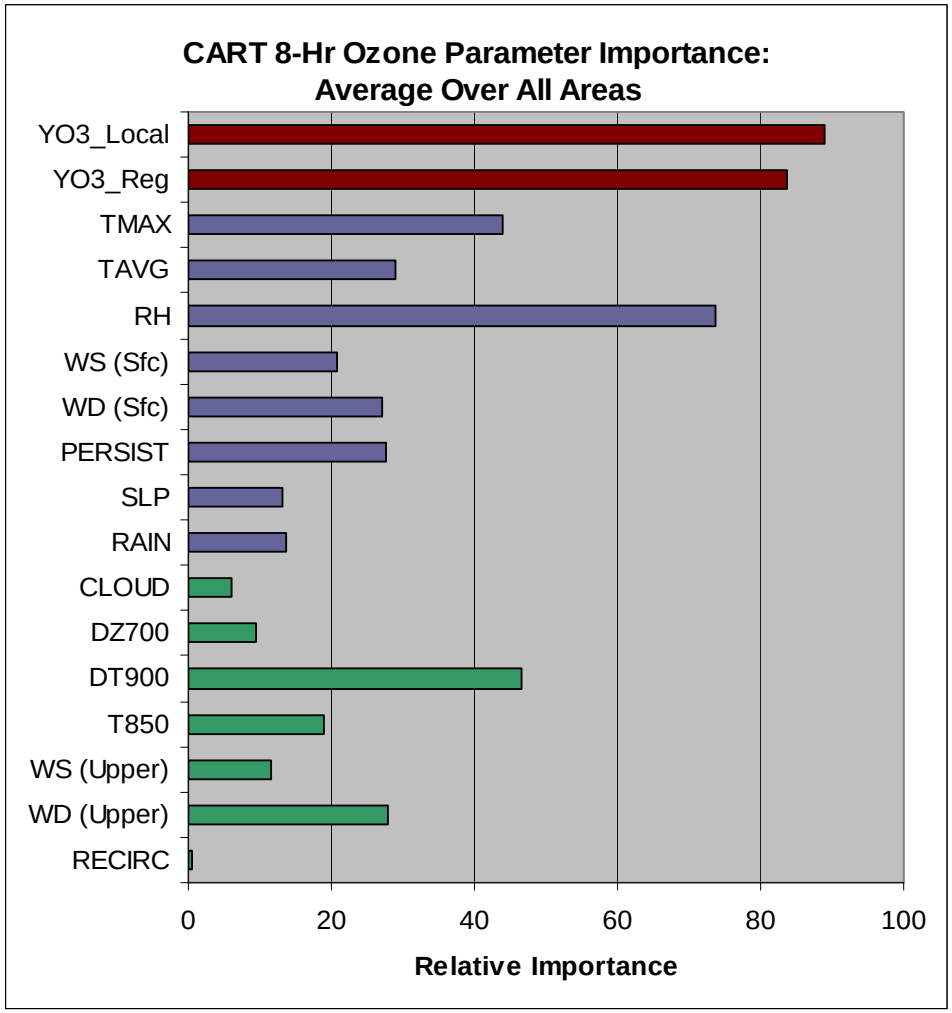
Effect of Recirculation (Possible Gulf Breeze) on PM2.5



Persistence = index of recirculation = $\overline{\mathbf{u}} / |\overline{u}|$

24-hr average PM2.5: 0.3 to 1.5 ug/m3 greater for days with recirculation (possible gulf breeze)

Classification & Regression Tree Analysis for Ozone

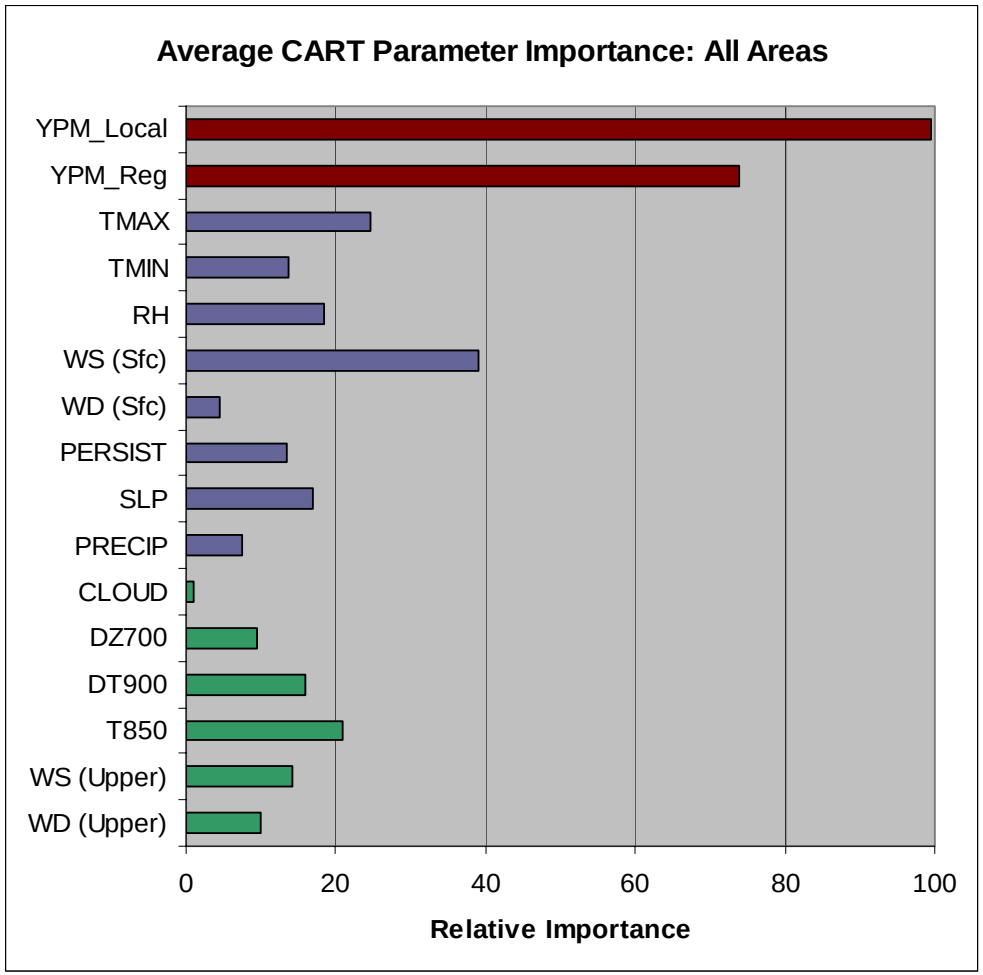


Important parameters:

- Prior day ozone
- Relative humidity
- Stability
- Temperature
- Wind direction (sfc & aloft)
- Persistence

Classification accuracy lower by only 3 percent with met only

Classification & Regression Tree Analysis for PM2.5

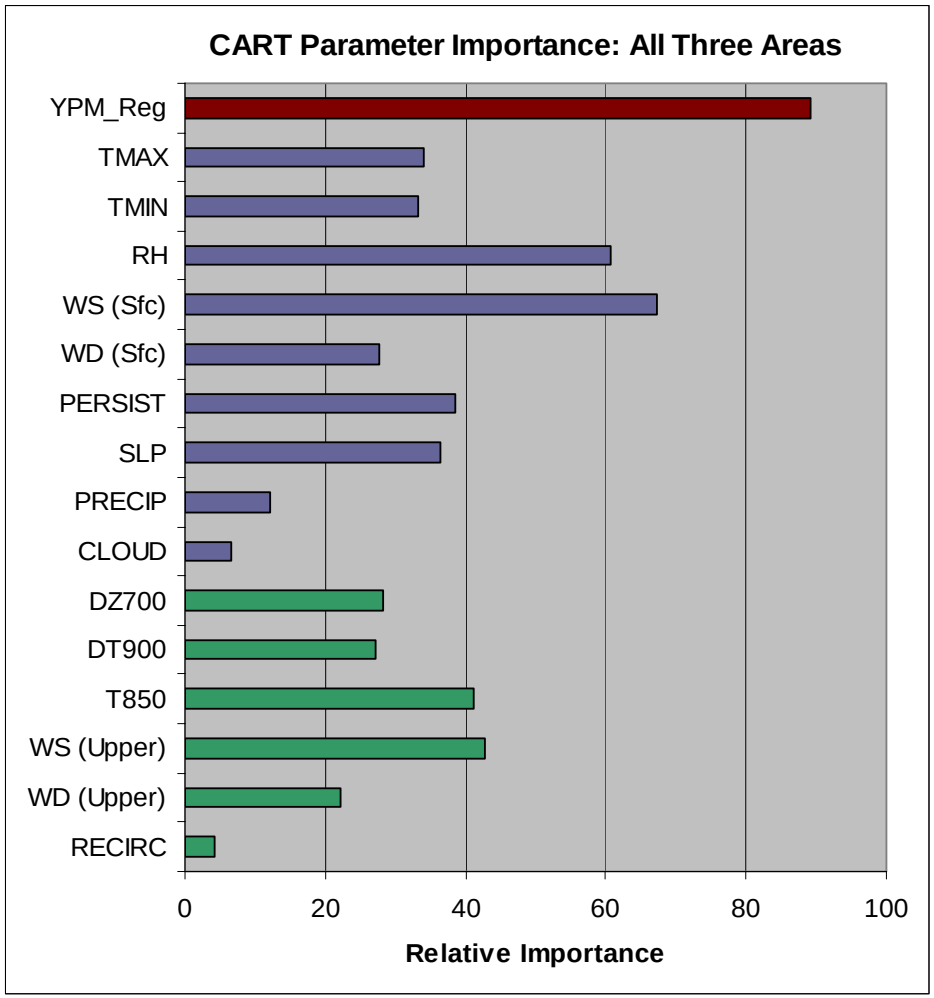


Important parameters:

- Prior day PM2.5
- Wind speed (sfc)
- Temperature
- Relative humidity

Classification accuracy lower by 6 percent with met only

Classification & Regression Tree Analysis for Visibility



Important parameters:

- Prior day PM2.5
- Wind speed (sfc & aloft)
- Relative humidity
- 850 mb temperature

Classification accuracy lower by 7 percent with met only

Example Findings from Data Analyses

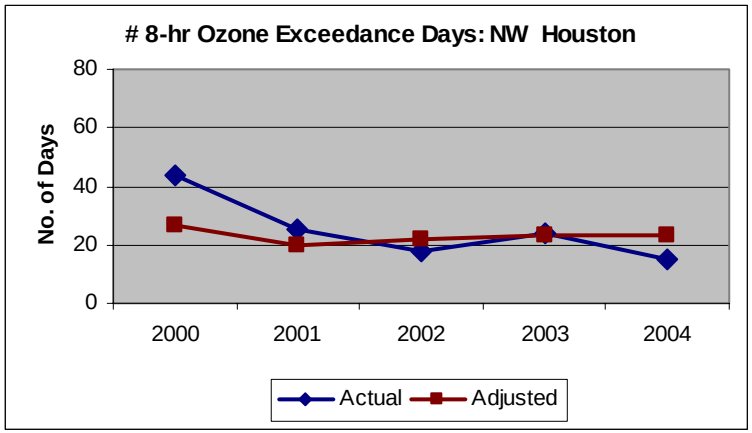
- Considering all areas
  - Higher ozone concentrations occur under conditions of low surface wind speeds and W to SE winds aloft
  - Higher PM2.5 concentrations occur under conditions of low surface wind speeds and N to E winds aloft
- The gulf breeze circulation contributes to air quality issues along the Gulf Coast

Example Findings from Data Analyses

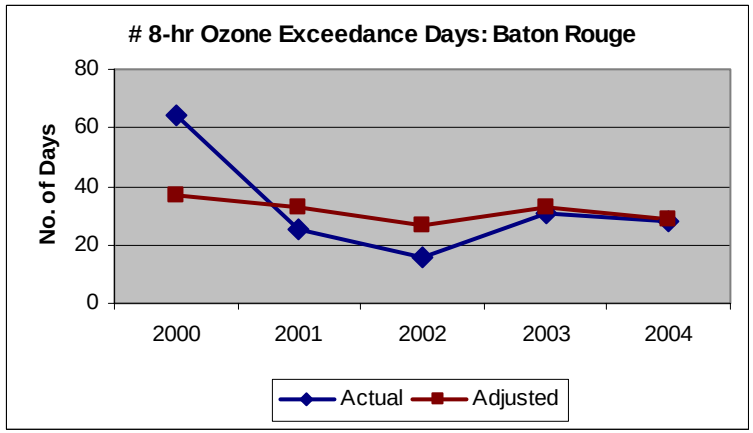
- CART analysis results indicate that there are multiple pathways to high ozone and PM2.5
- A key distinguishing factor among different types of high ozone days is wind direction
- Different mechanisms lead to high PM2.5 concentrations during different times of the year
  - Regional build up of PM2.5 important during warmer months
  - Low temperatures, low wind speeds and stability important during colder months

Meteorologically Adjusted Air Quality Trends: Ozone

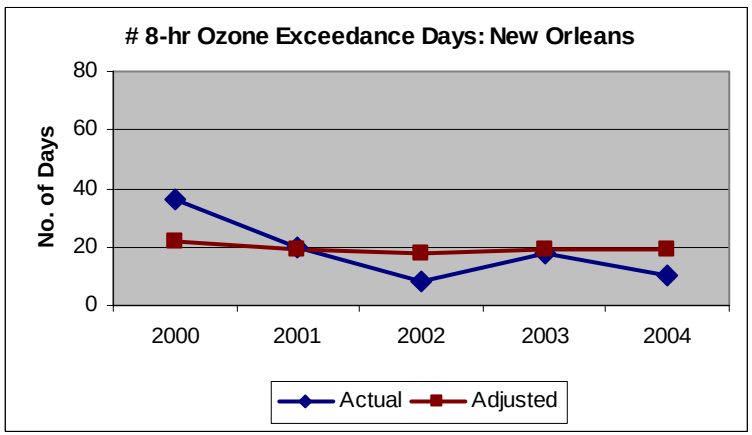
NW Houston



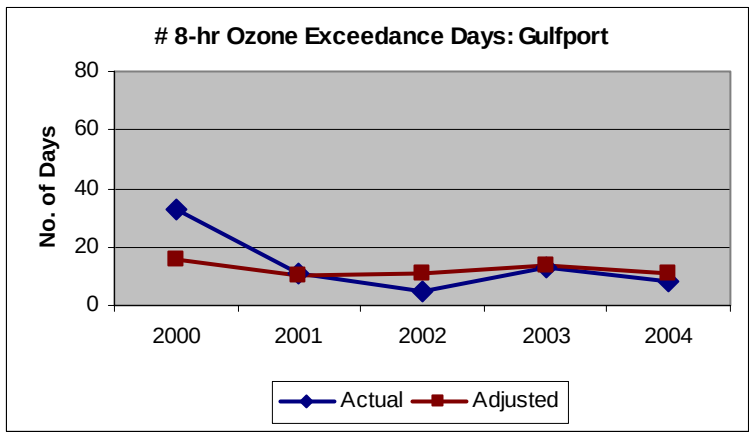
Baton Rouge



New Orleans

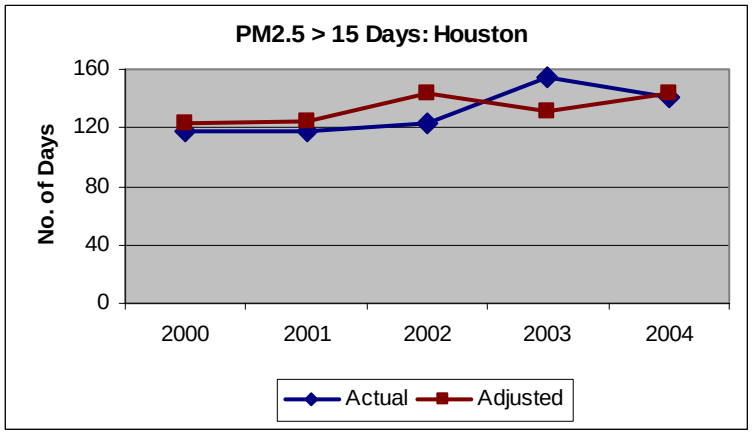


Gulfport

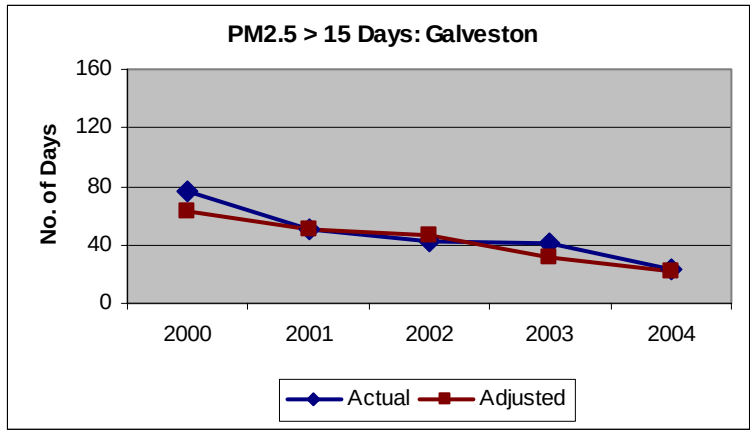


Meteorologically Adjusted Air Quality Trends: PM2.5

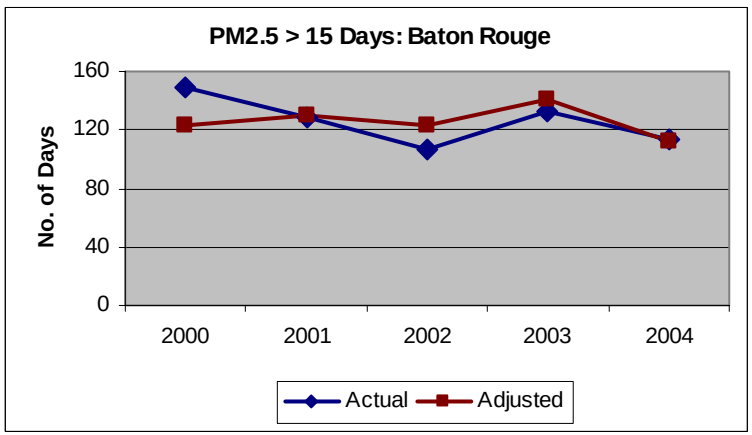
Houston



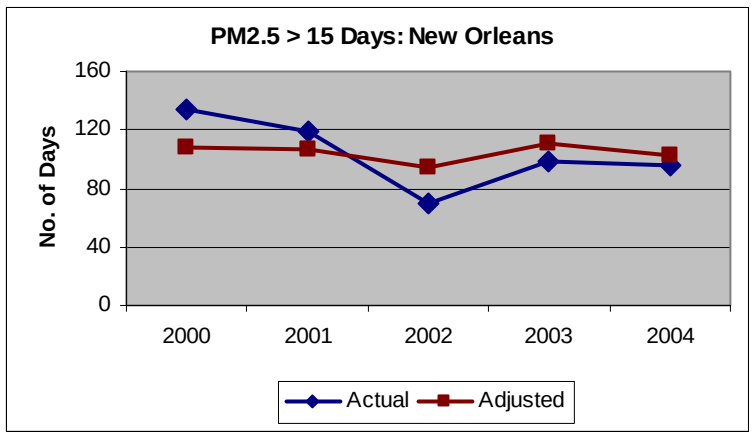
Galveston



Baton Rouge



New Orleans



Example Findings from Trends Analyses

- Met adjusted values vary less from year to year than actual values
- High observed ozone for 2000 and low ozone for 2002 attributable to meteorology
- Year-to-year trends between 2000 and 2004
  - Relatively flat for ozone
  - Slightly upward for PM2.5 for Houston
  - Downward for PM2.5 for other areas
- Trends consistent with slight decreases in onshore emissions between 1999 and 2005

Data Synthesis & Integration Study Documentation

- User's Guide – provides information on functionality and features of the tool
- Technical Reference Manual – provides information on
  - System requirements
  - Installation & maintenance of the tool
  - Oracle database and ACCESS 2003 options
- Data Analysis Report (Draft) – summarizes methods & results of data analyses