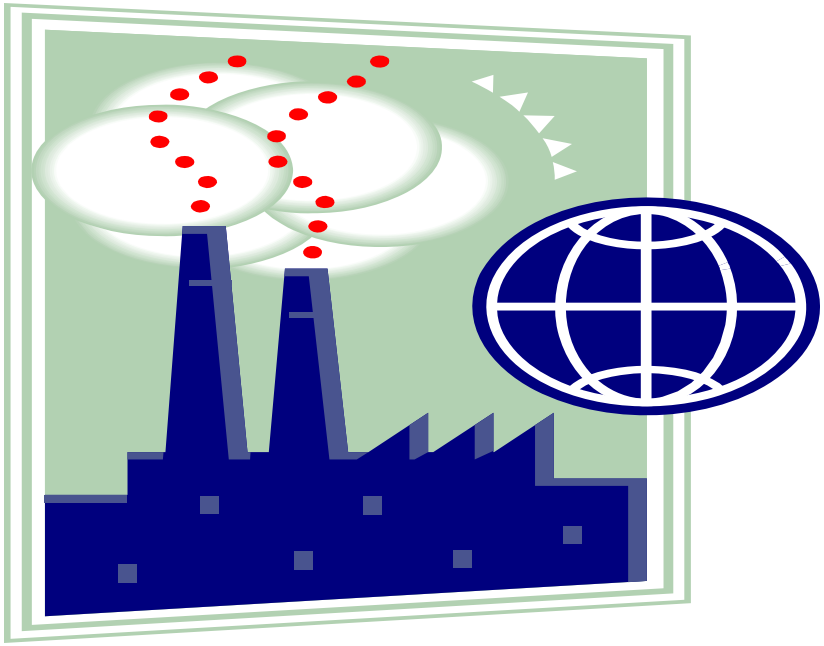
MM5-AERMOD TOOL



Ad Hoc Meteorological Modeling Group
June 14, 2007

Overview of Presentation

- Problem Statement and Objective
- MM5-AERMOD Tool Description
- Example Test Case - Detroit
- Summary of Issues/Concerns
- Next Steps

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- MACTEC - Contractor

Problem Statement

- Meteorological data are key inputs to air quality models such as AERMOD
- Currently, NWS data are used in most cases:
  - Observation sites may not be representative (10-100's km away)
  - Upper air data are sparsely located, especially in mountainous areas
- Significant gaps in NWS data for calms and variable winds; frequency of gaps has increased with ASOS and METAR
- Onsite meteorological data collection is expensive and time consuming

Potential Solution

- These problems may be alleviated by using outputs from prognostic gridded meteorological models
- Gridded meteorological models routinely generate datasets that could be beneficial for use in dispersion models like AERMOD
  - In fact, gridded data are already used in CALMET/CALPUFF

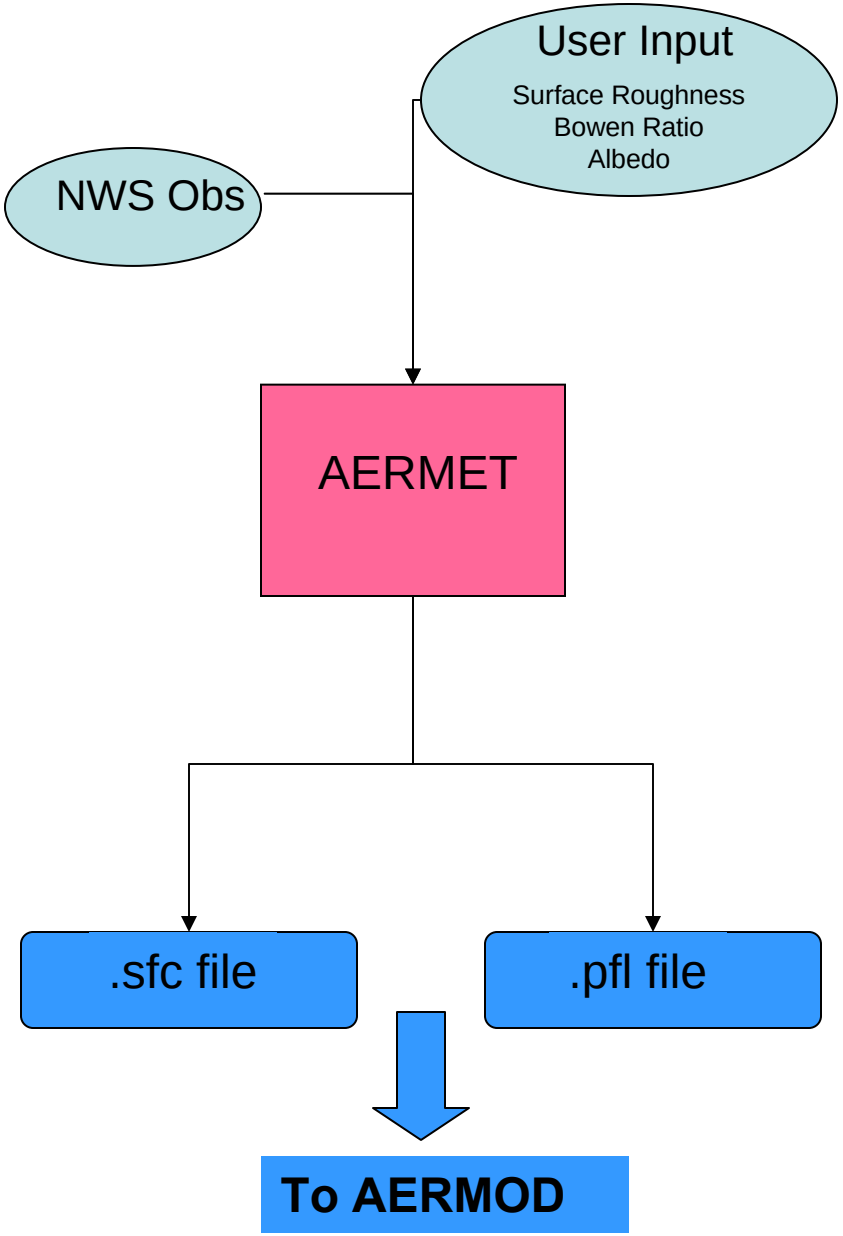
OBJECTIVE:
Develop MM5-AERMOD Tool that . . .

- Provides spatially consistent AERMOD inputs in 3 dimensions
  - Surface and Upper-air data located in same grid cell
  - Hourly values for every grid cell
  - Grid cell selected based on application site
- Allows AERMOD to use parameters calculated by MM5's advanced atmospheric physics (e.g., Heat Flux, Monin-Obukhov length)
- Uses MM5 data to calculate parameters previously calculated from NWS observations

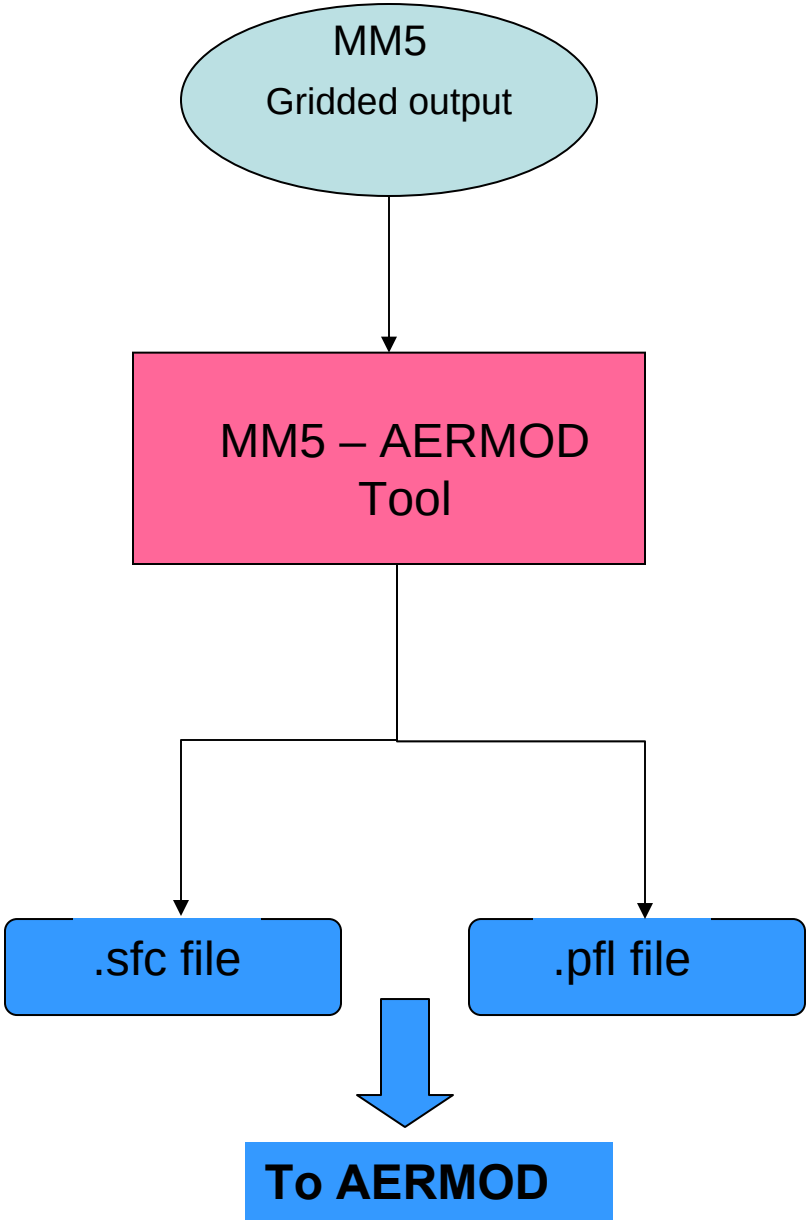
MM5-AERMOD Tool and Functions

- Tool is a Fortran program that operates in a Windows or Linux environment (No GUI)
- Extracts and processes MM5 gridded meteorological data for user-specified location
  - Some variables are directly passed from MM5 to the output files
  - Some variables are interpolated from four surrounding grid cells to the central location nearest the point of interest
  - Some variables are calculated based on the available MM5 data
- Outputs a surface file and a profile file formatted for input to AERMOD

Traditional AERMET Application



MM5-AERMOD Tool Application



AERMOD Parameters Directly Input from MM5

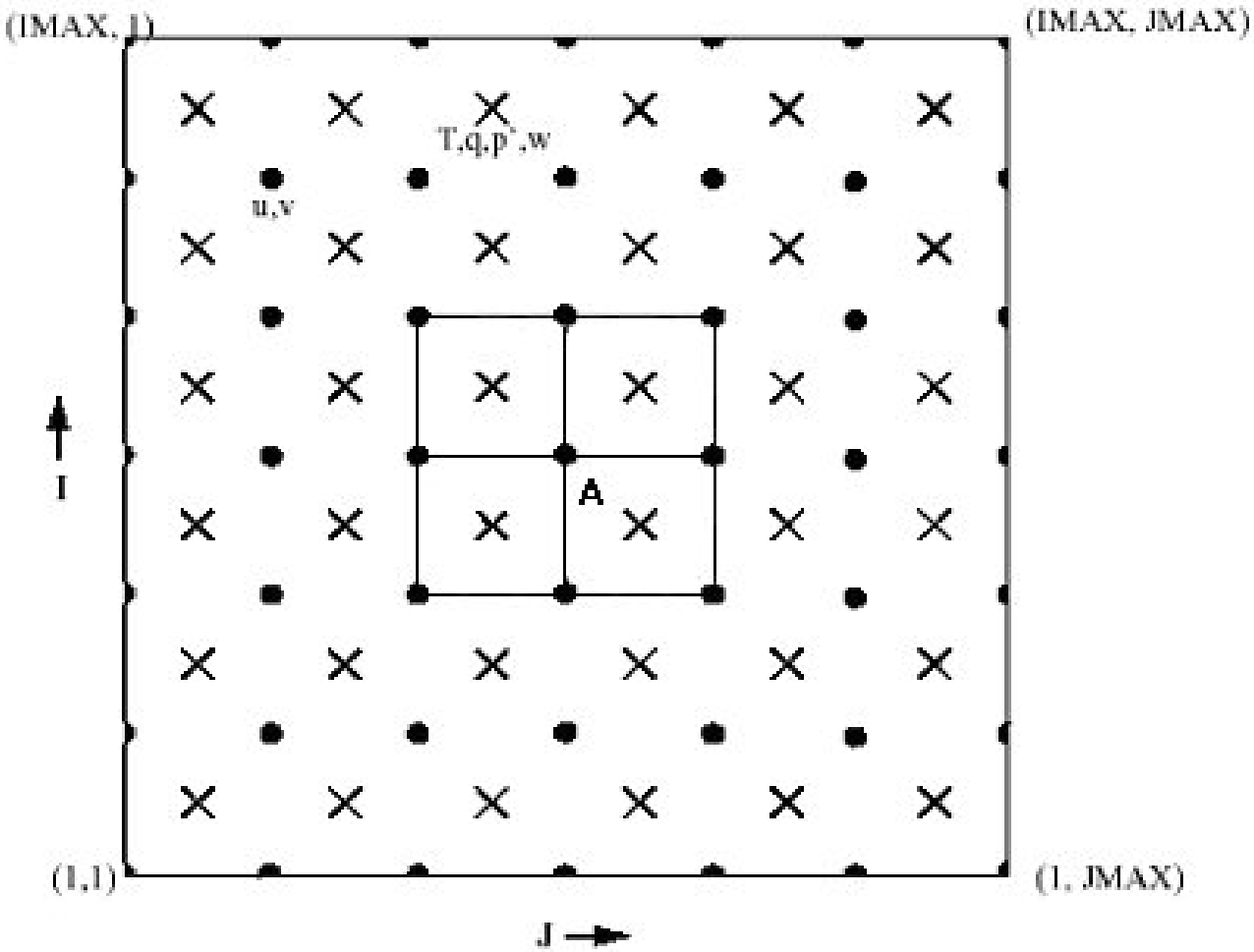
- Sensible heat flux
- Surface friction velocity
- Surface roughness length
- Albedo
- Precipitation type and amount
- Wind speed/direction
- 2 m temperature

AERMOD Parameters Computed from MM5 Data

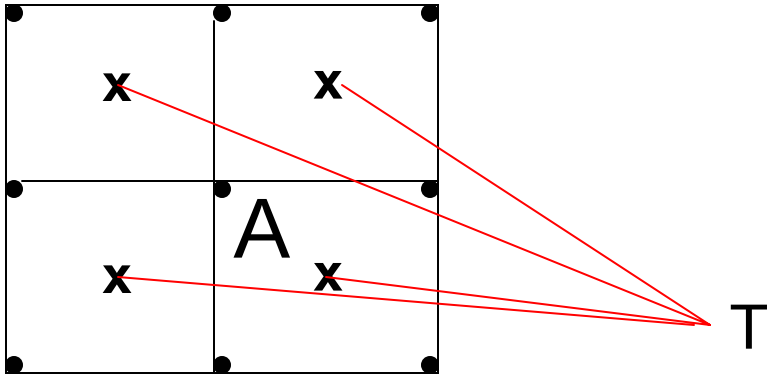
- Convective velocity scale
- Convective mixing height
- Mechanical mixing height
- Lapse rate above mixing height
- Monin-Obukhov length
- Bowen ratio
- Relative humidity
- Surface pressure
- Cloud cover (only used for deposition)

How Interpolation of MM5 Gridded data is performed

Schematic Representation Showing the Horizontal Staggering of the Dot (●) and Cross (x) Grid Points



Interpolation of MM5 Gridded Data



- Letter “A” represents the point of interest.
- Vector quantities (e.g. WS) are available at the “dot point” nearest to “A”
- Scalar quantities (e.g. T) from each of the four “cross points” are interpolated to the center “dot point”

MM5-AERMOD Tool Output Files

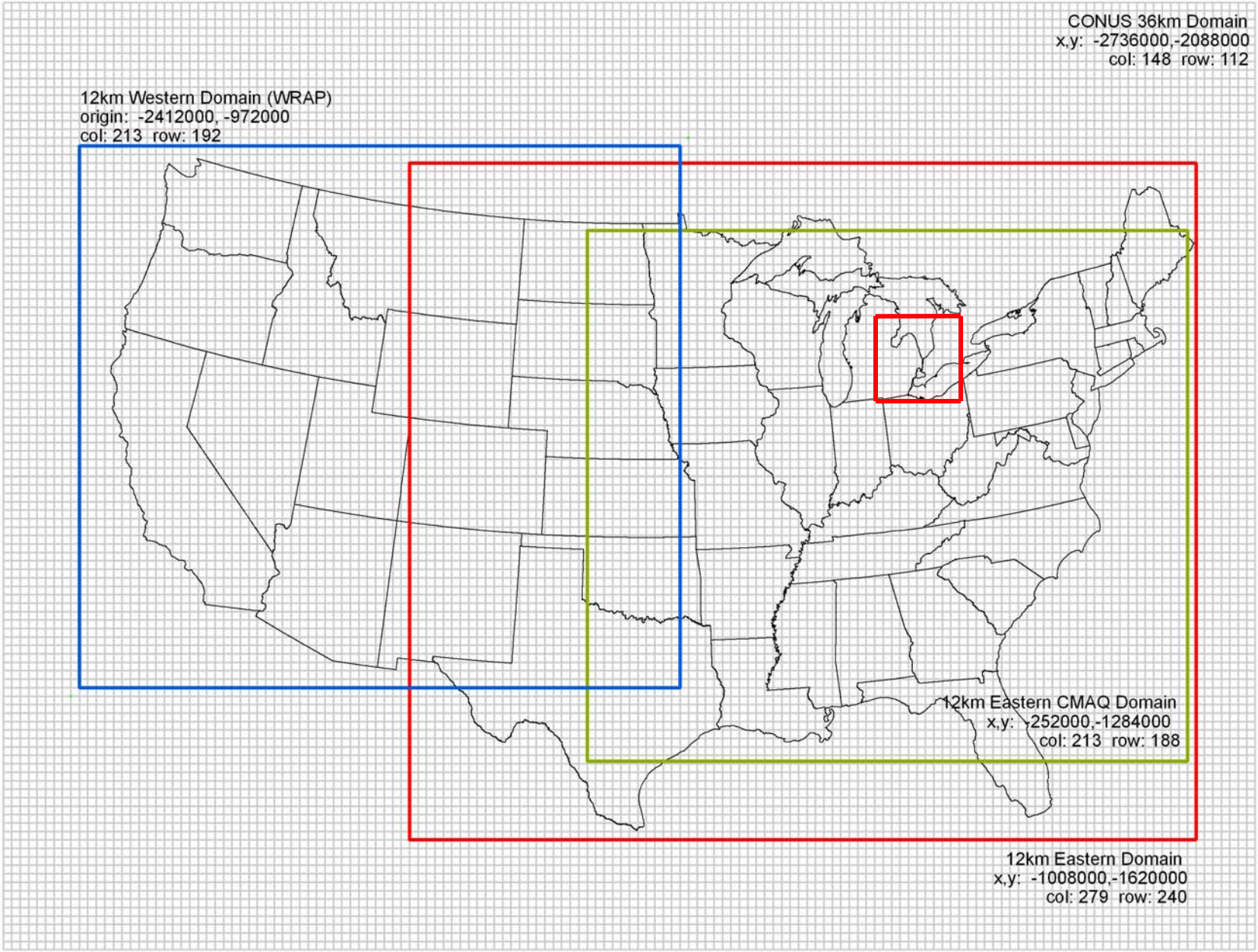
- AERMOD Ready Input Files
  - Surface file--contains wind direction/speed, temperature, relative humidity, pressure, cloud cover and precipitation. Also contains boundary layer variables.
  - Profile file--contains one or more levels of winds, temperature, and if available, horizontal wind direction fluctuations and vertical wind speed fluctuations
- Log File--contains user inputs, MM5 grid cells from which data are extracted, informational messages for cases where a meteorological variable may have been altered (e.g., out of range)

Example Test Case – Detroit Area

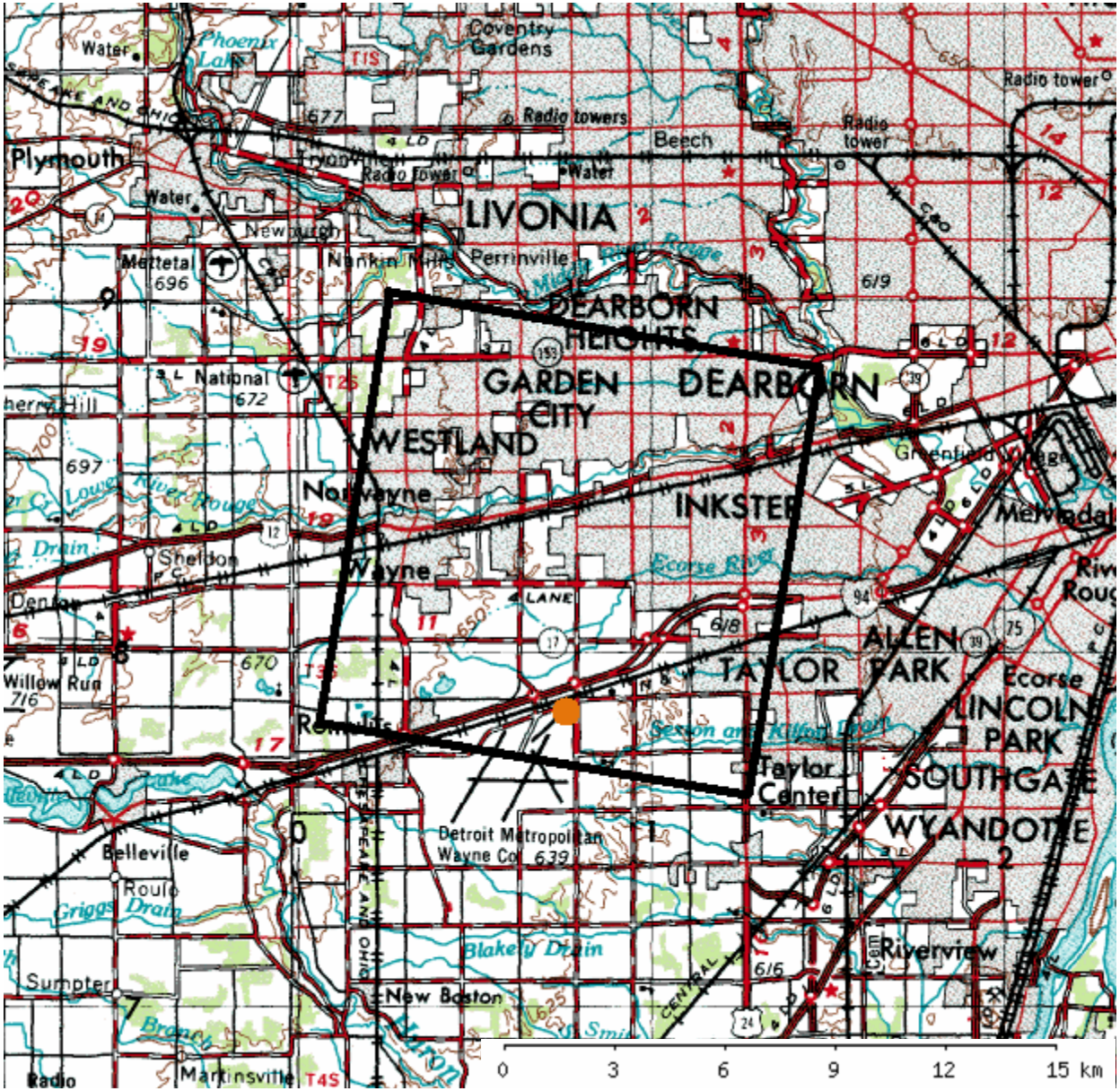
- Apply MM5-AERMOD Tool
  - Extract 2002 MM5 data for Detroit Metropolitan Airport (DTW) grid cell
- Apply traditional NWS-AERMET approach
  - Use 2002 DTW ISHD and DTX upper air data
- Analyze, compare, document results

Example Test Case – Detroit Area

- MM5 12 km meteorological data for 2002 available for an eastern U.S. domain
- File sizes of the MM5 12 km eastern domain are approximately 16.5 GB per 5.5 days of simulation time, or about 1.2 TB for a one year simulation
- Using the EPA supercomputer a 30x30 subgrid was extracted for the area around Detroit to reduce the file sizes


CONUS 36km Domain
x,y: -2736000,-2088000
col: 148 row: 112
12km Western Domain (WRAP)
origin: -2412000, -972000
col: 213 row: 192
12km Eastern CMAQ Domain
x,y: -252000,-1284000
col: 213 row: 188
12km Eastern Domain
x,y: -1008000,-1620000
col: 279 row: 240

MM5 12km Grid Cell for DTW

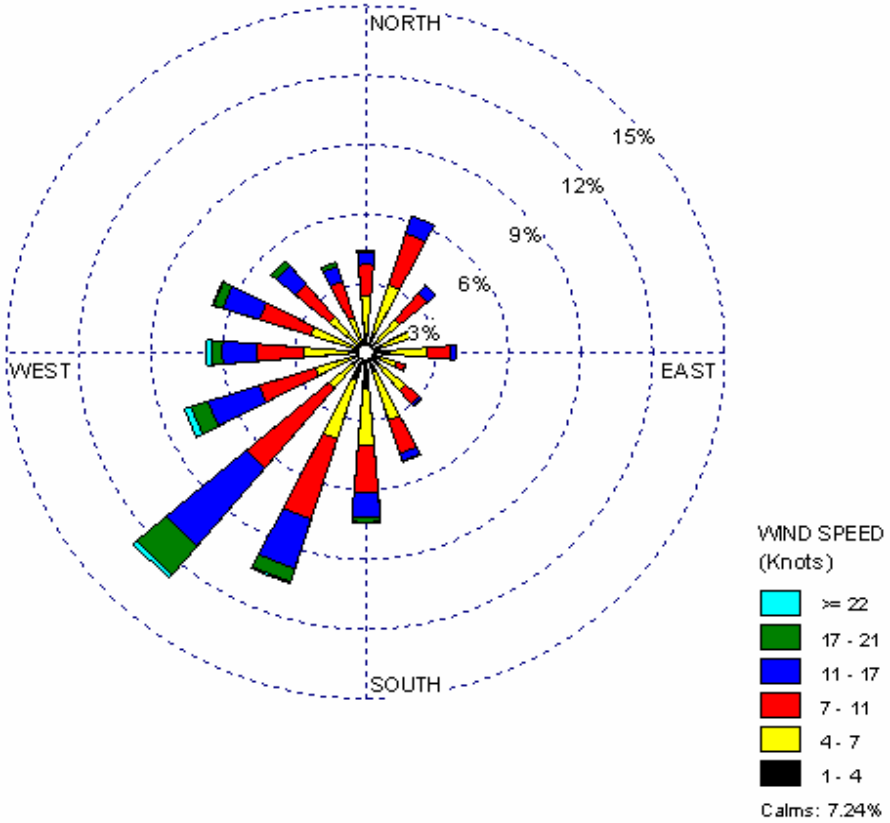


MM5-AERMOD Tool Input File

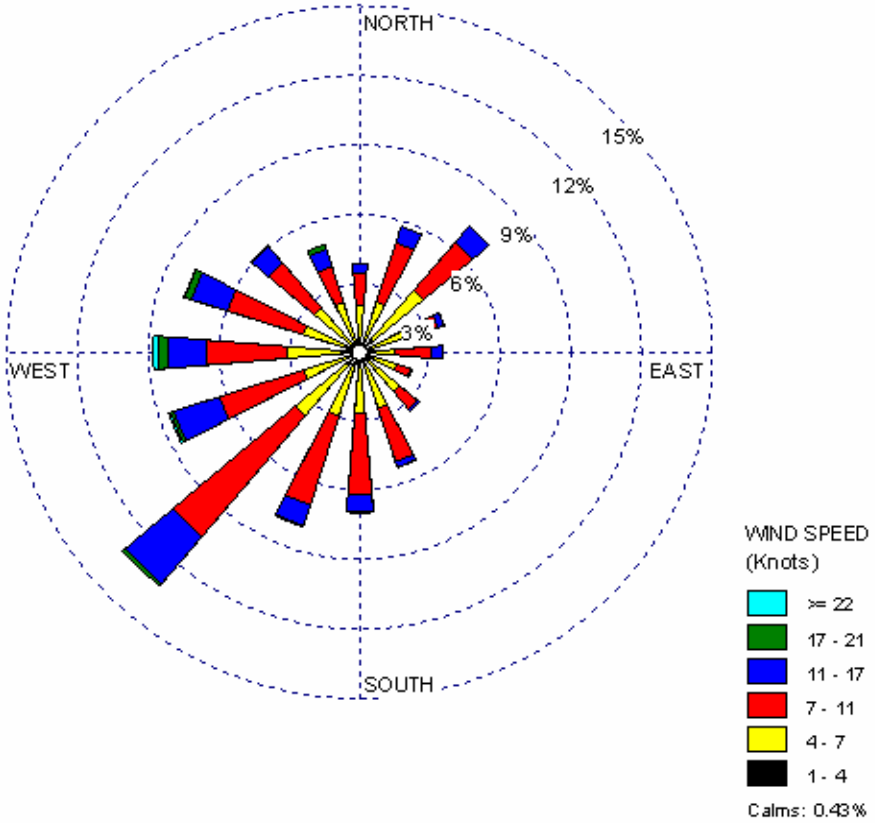
&userinp	First line of input file
start_time = '2002-06-20-01:00:00.0000',	Model output start time
end_time = '2002-06-28-00:00:00.0000',	Model output end time
site_id = '14822',	Site Identification number
site_lat = 42.40,	Latitude at site
site_lon = -83.00,	Longitude at site
jx_orig = 165,	Subgrid x offset SW corner
iy_orig = 150,	Subgrid y offset SW corner
utc_adj = 5,	UTC to local time adjustment
met_path = 'AERMOD',	Path name (hardwired)
aermod_sfc = 'Detroit.sfc',	Output surface file name
aermod_pfl = 'Detroit.pfl',	Output profile file name
mm5_file = 'V:\2002-12\02Jun19\detroit.dat',	MM5 data filename and path
'V:\2002-12\02Jun23\detroit.dat',	MM5 data filename and path
&END	Last line of input file

Detroit 2002 Windroses

NWS (DTW)

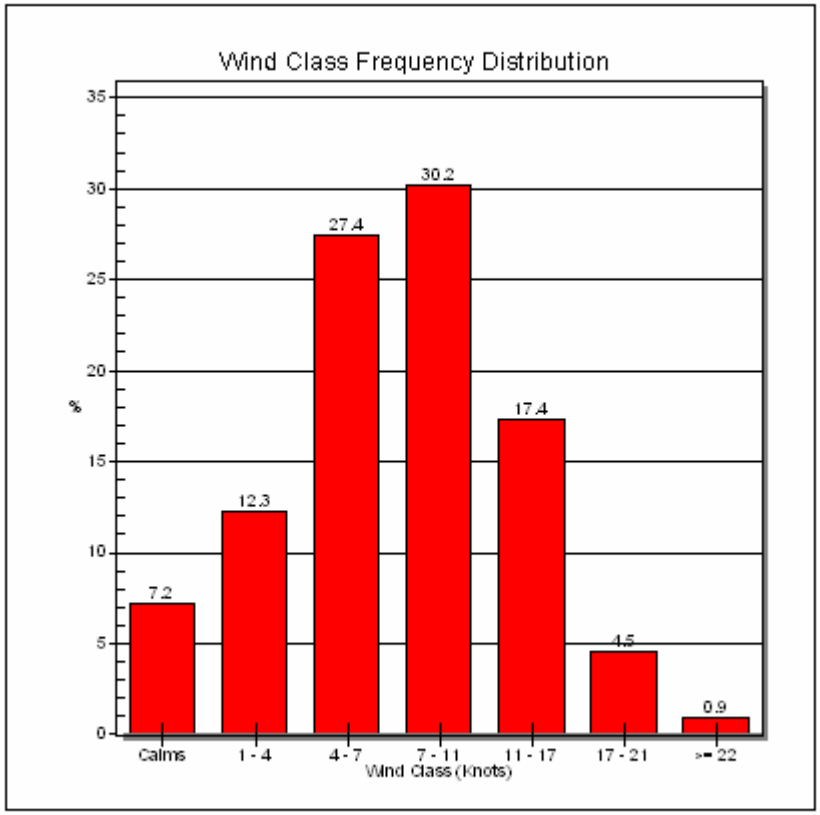


MM5 (12km Grid Cell)

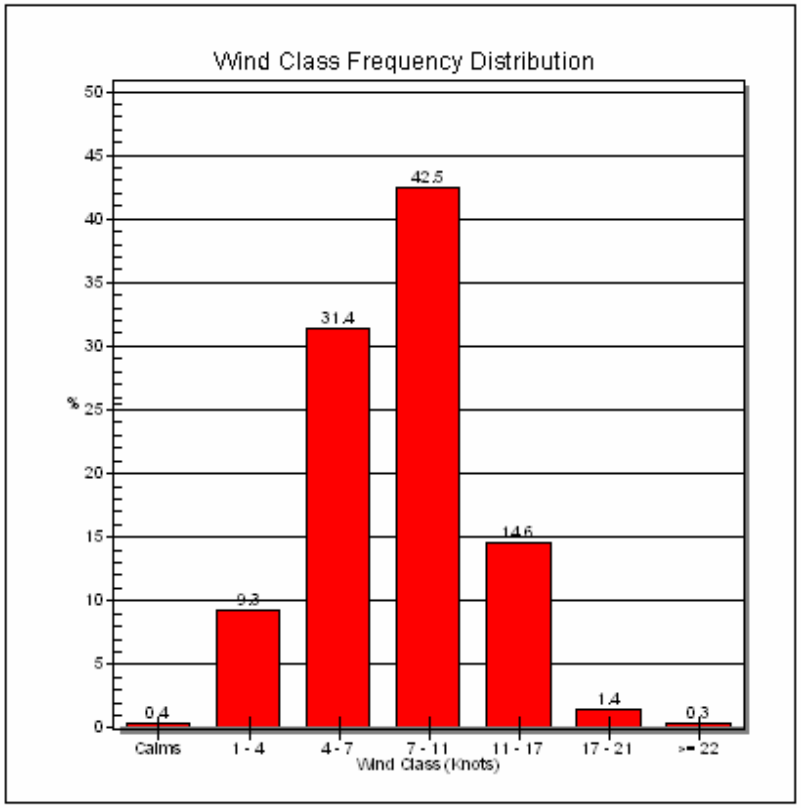


Detroit 2002 WS Frequency Distributions

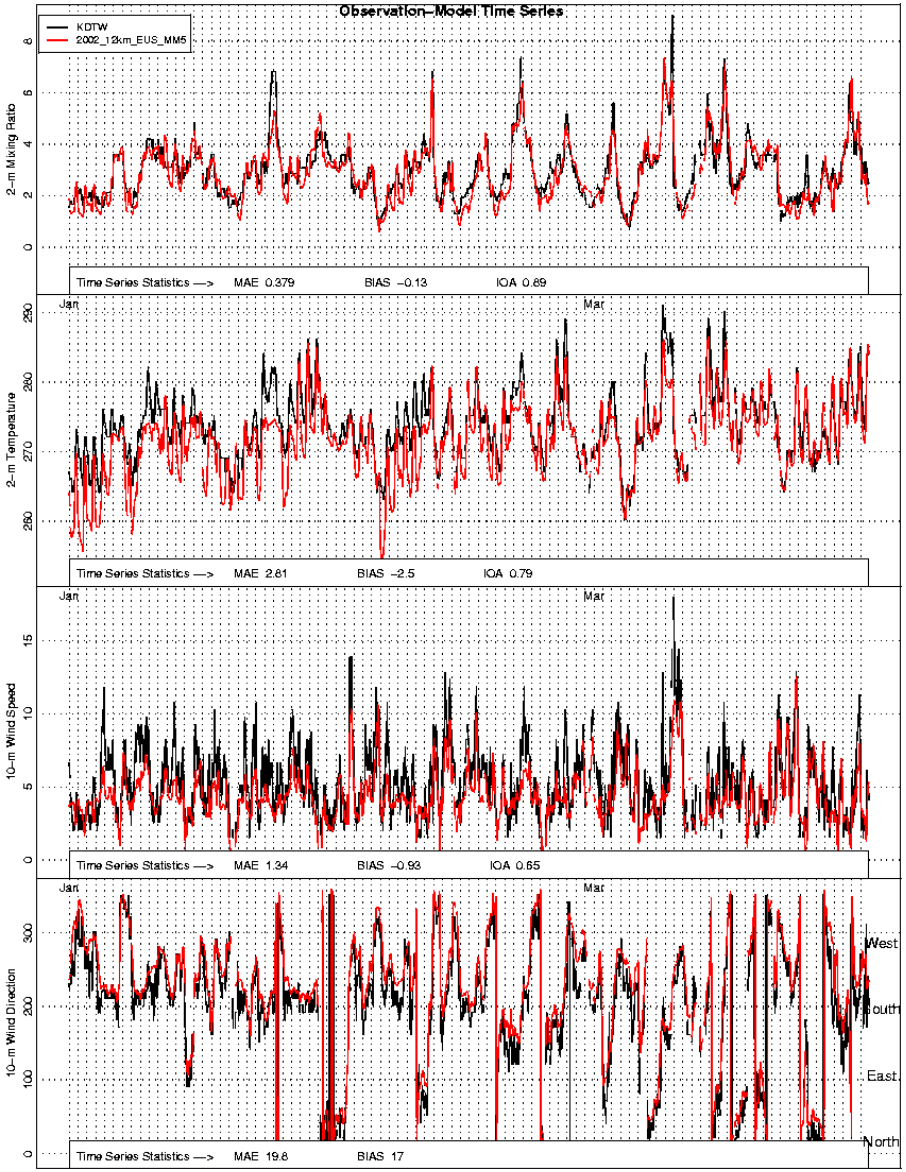
NWS (DTW)

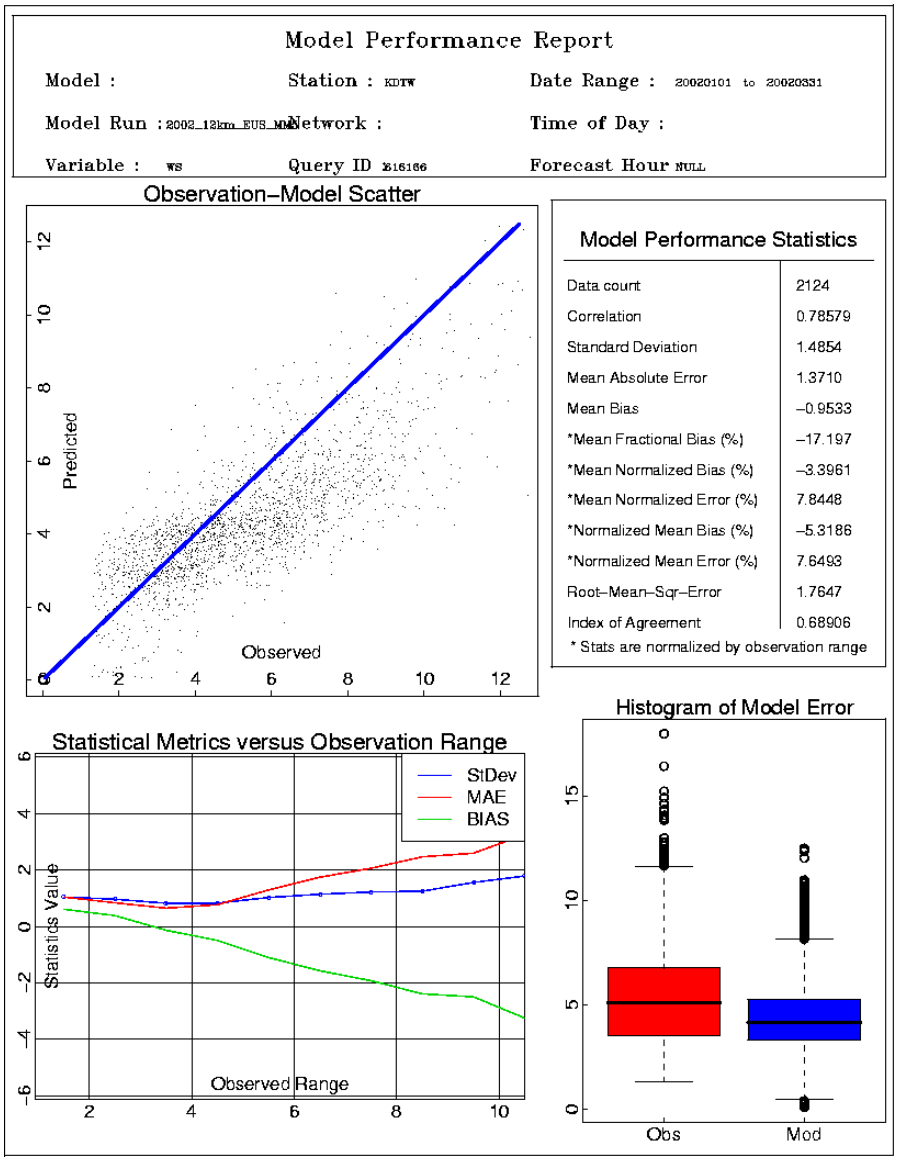


MM5 (12km Grid Cell)

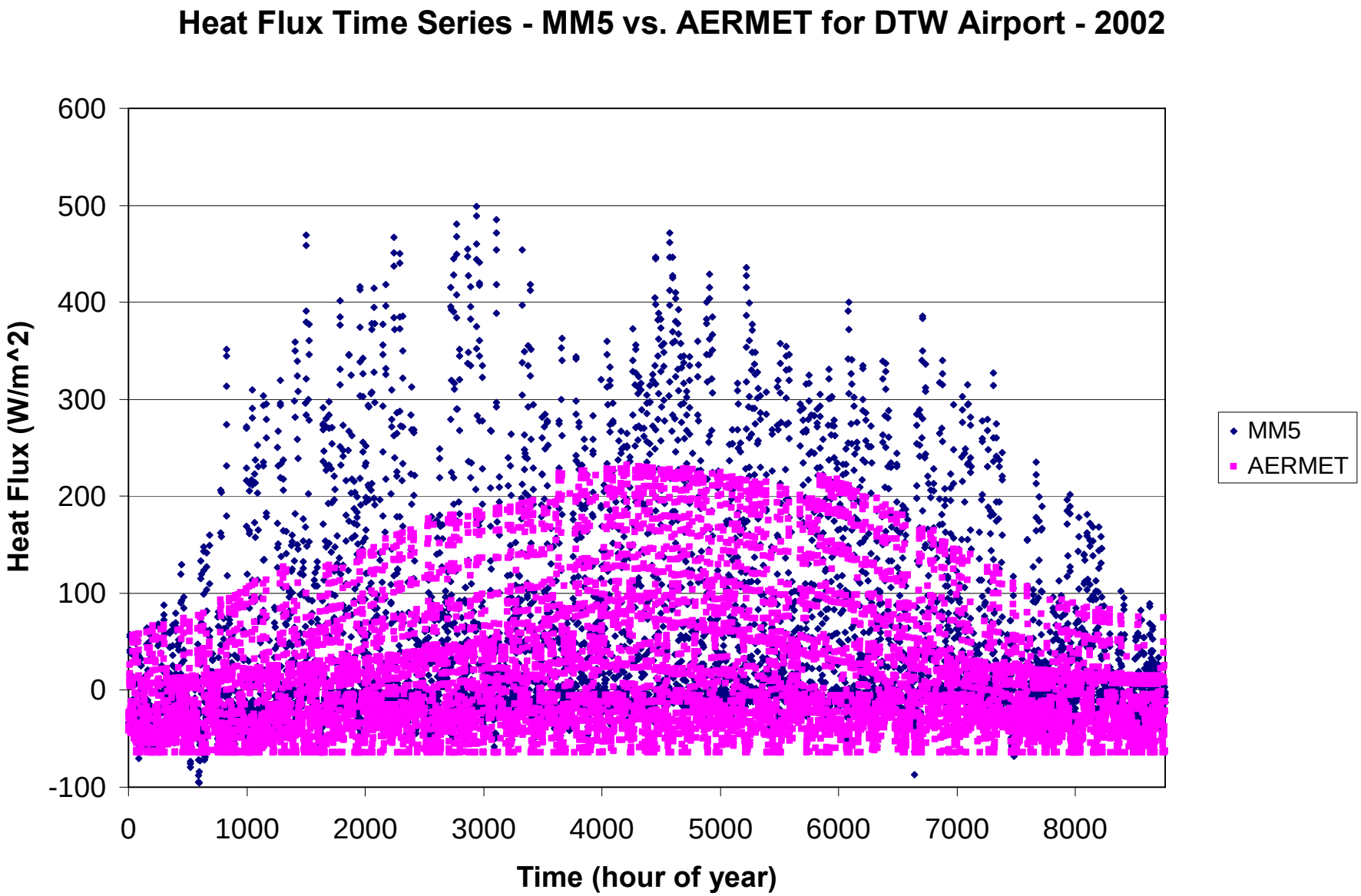


Detroit 2002 MM5 Evaluations

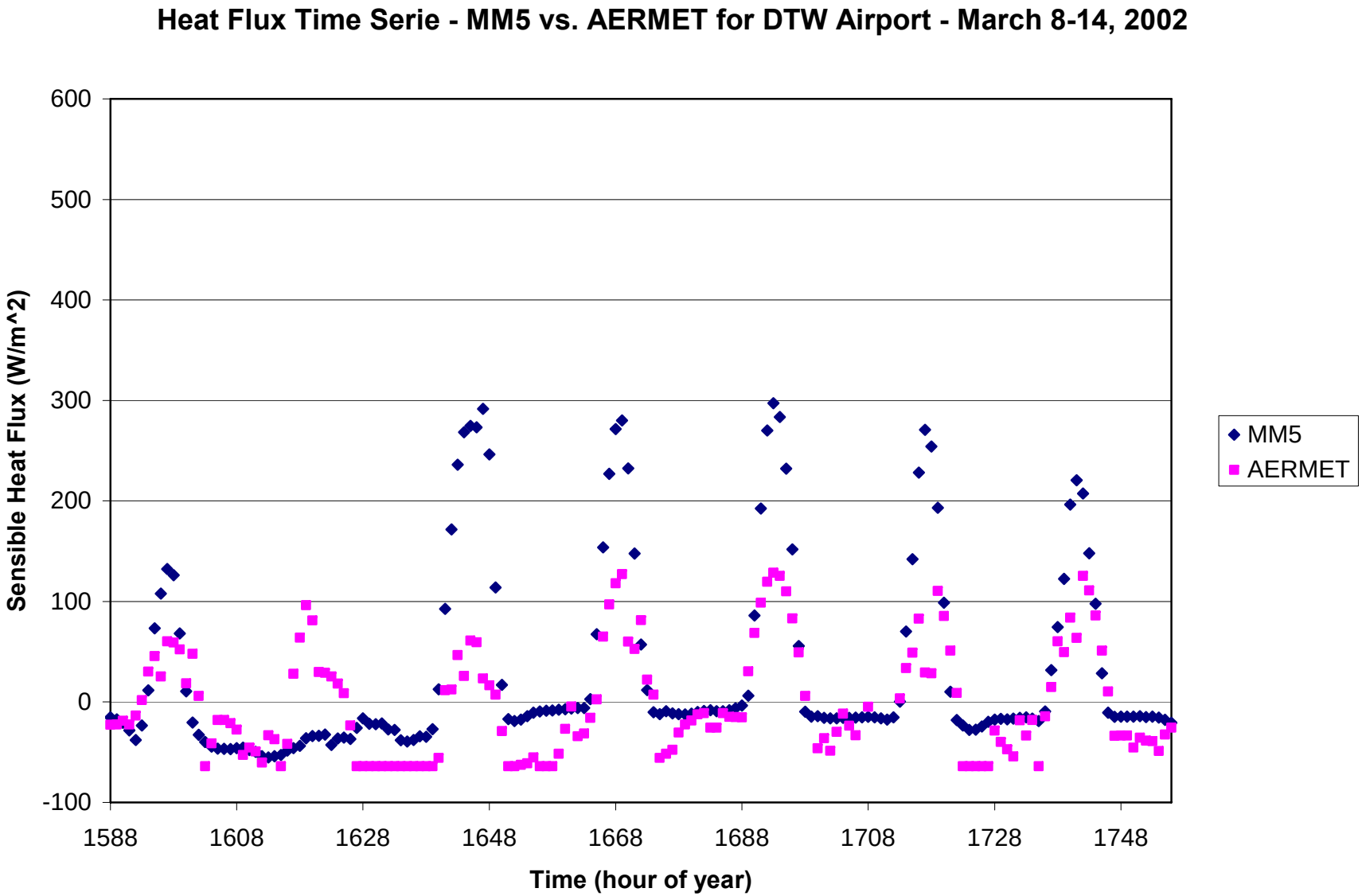




Detroit 2002 Heat Flux Comparisons



Detroit 2002 Heat Flux Comparisons



Detroit 2002 MM5-NWS AERMOD Comparisons – Source Descriptions

Source ID *	Height (m)	Exit Temp. (K)	Exit Velocity (m/s)	Diameter (m)	Downwash
00NBND	0.0	0	0.0	0.0	None – no building
10BYND	10.0	300	15.0	0.5	None – no building
10BYDW	10.0	293	1.0	2.4	Squat; source on NE corner
10NBND	10.0	0	0.0	0.0	None – no building
35BYND	35.0	432	11.7	2.4	None – no building
35BYDW	35.0	432	11.7	2.4	Squat; source on NE corner
35BYDW2	35.0	432	11.7	2.4	Squat; source 4 Hb off NE corner **
50NBND	50.0	0	0.0	0.0	None – no building
100BYND	100.0	425	26.5	5.6	None – no building

* Source ID is a combination of the source release height (00, 10, 35, 50, or 100), buoyant (BY) or non-buoyant (NB) release, and downwash (DW) or no downwash (ND)

** Hb = building height

Detroit 2002 MM5-NWS AERMOD Comparisons – Model Results

24-hr Averages – Rural

Source ID	H1H (μg m^{-3}/g s^{-1})		MM5/NWS Ratio	H2H (μg m^{-3}/g s^{-1})		MM5/NWS Ratio
	AERMET	MM5		AERMET	MM5	
00NBND	3558.43	69048.46	19.40	2935.86	27708.71	9.44
10NBND	222.81	368.19	1.65	204.31	312.09	1.53
10BYND	111.44	135.13	1.21	90.25	103.91	1.15
10BYDW	131.67	305.53	2.32	130.73	250.58	1.92
35BYND	2.57	2.02	0.79	2.49	1.70	0.69
35BYDW	22.95	25.93	1.13	22.09	25.41	1.15
35BYDW2	1.77	2.02	1.14	1.70	1.70	1.00
50NBND	7.09	10.10	1.42	6.89	7.90	1.15
100BYND	0.09	0.13	1.48	0.08	0.12	1.66

* Source ID is a combination of the source release height (00, 10, 35, 50, or 100), buoyant (BY) or non-buoyant (NB) release, and downwash (DW) or no downwash (ND)

** Hb = building height

Meteorology Comparison for MM5 H1H 24-hr Average Day

					NWS DATA						MM5 DATA					
YR	MN	DY	JDY	HR	HFLUX	USTAR	WSPD	WDIR	UREF	TEMP	HFLUX	USTAR	WSPD	WDIR	UREF	TEMP
2	12	11	345	1	-33.8	0.290	3.10	241.	10.0	272.5	-3.5	0.030	1.62	226.	19.0	270.2
2	12	11	345	2	-17.6	0.253	2.60	268.	10.0	271.4	-2.1	0.021	1.38	223.	19.0	270.7
2	12	11	345	3	-27.4	0.308	3.10	190.	10.0	269.9	-0.9	0.011	1.09	221.	19.0	271.5
2	12	11	345	4	-12.4	0.120	2.10	192.	10.0	270.4	-0.6	0.009	0.77	220.	19.0	271.7
2	12	11	345	5	-999.0	-9.000	0.00	0.	10.0	269.9	-0.6	0.009	0.49	217.	19.0	271.7
2	12	11	345	6	-19.5	0.244	2.60	180.	10.0	267.5	-0.6	0.009	0.20	216.	19.0	271.7
2	12	11	345	7	-999.0	-9.000	0.00	0.	10.0	268.8	-0.6	0.009	0.12	27.	19.0	271.8
2	12	11	345	8	-999.0	-9.000	0.00	0.	10.0	269.2	-0.7	0.010	0.42	33.	19.0	271.9
2	12	11	345	9	-999.0	-9.000	0.00	0.	10.0	269.2	-0.7	0.011	0.64	39.	19.0	272.0
2	12	11	345	10	19.4	-9.000	0.00	0.	10.0	267.0	-0.8	0.013	0.73	45.	19.0	272.2
2	12	11	345	11	48.7	-9.000	0.00	0.	10.0	266.4	-0.9	0.020	0.70	52.	19.0	272.7
2	12	11	345	12	74.8	-9.000	0.00	0.	10.0	268.8	-0.4	0.122	0.54	65.	19.0	274.2
2	12	11	345	13	15.2	-9.000	0.00	0.	10.0	270.4	9.7	0.197	0.44	83.	19.0	274.8
2	12	11	345	14	34.5	-9.000	0.00	0.	10.0	268.8	8.4	0.185	0.38	116.	19.0	275.3
2	12	11	345	15	23.3	0.204	1.50	336.	10.0	272.0	2.2	0.130	0.39	160.	19.0	275.4
2	12	11	345	16	-2.6	0.232	2.10	2.	10.0	273.1	-0.6	0.038	0.58	187.	19.0	275.1
2	12	11	345	17	-4.2	0.086	1.50	347.	10.0	274.9	-0.9	0.022	0.76	201.	19.0	274.2
2	12	11	345	18	-999.0	-9.000	0.00	0.	10.0	275.4	-0.8	0.014	0.93	215.	19.0	273.7
2	12	11	345	19	-999.0	-9.000	0.00	0.	10.0	275.9	-1.1	0.015	1.14	226.	19.0	273.2
2	12	11	345	20	-999.0	-9.000	0.00	0.	10.0	275.9	-2.3	0.023	1.42	235.	19.0	272.3
2	12	11	345	21	-999.0	-9.000	0.00	0.	10.0	275.9	-4.3	0.033	1.74	237.	19.0	271.4
2	12	11	345	22	-999.0	-9.000	0.00	0.	10.0	274.9	-7.3	0.047	2.08	238.	19.0	270.4
2	12	11	345	23	-999.0	-9.000	0.00	0.	10.0	275.4	-11.0	0.063	2.44	239.	19.0	269.6
2	12	11	345	24	-999.0	-9.000	0.00	0.	10.0	275.4	-14.6	0.080	2.77	240.	19.0	269.5

Next Steps

- Complete and document more detailed comparison of MM5-AERMOD Tool vs. NWS-AERMET results
- Conduct AERMOD “sensitivity” analyses with additional source types using meteorological inputs from each approach
- Fully analyze and document these additional model comparisons
- Extend comparisons to other geographic areas

Summary

- Tool allows for MM5 data to be extracted and formatted for input to the AERMOD model
- Preliminary comparisons show many similarities, but some significant differences between two approaches (MM5-AERMOD and NWS-AERMET) for Detroit area
- Use of gridded met data holds some promise, but additional study is needed to more fully understand and assess the methodology before acceptance of MM5 data for routine AERMOD applications