GEORGIA
DEPARTMENT OF NATURAL RESOURCES
ENVIRONMENTAL PROTECTION DIVISION

Photochemical Grid Modeling 101

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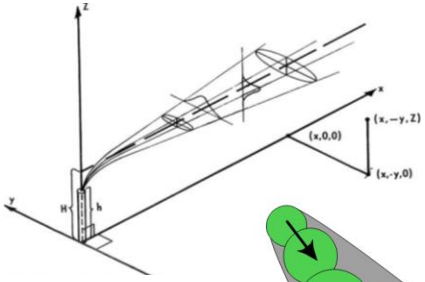
OUTLINE

- Background
- Model Inputs
- How the Models Work
- Model Performance Evaluations
- Probing Tools
- Computer Resources
- Personnel
- IT Support
- Example Applications

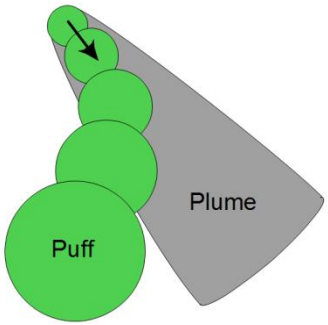
BACKGROUND

TYPES OF AIR QUALITY MODELS

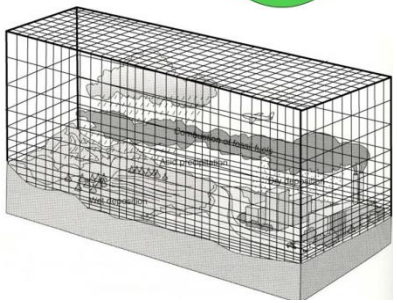
- **Steady-State Plume Model**
  - AERMOD



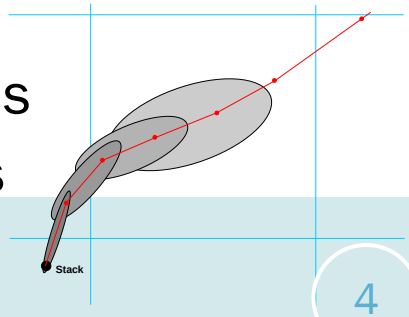
- **Lagrangian Puff Model**
  - Coordinate system follows air parcels.
  - CALPUFF, SCIPUFF, and SCICHEM



- **Eulerian Grid Model**
  - Coordinate system is fixed in space.
  - CAMx and CMAQ

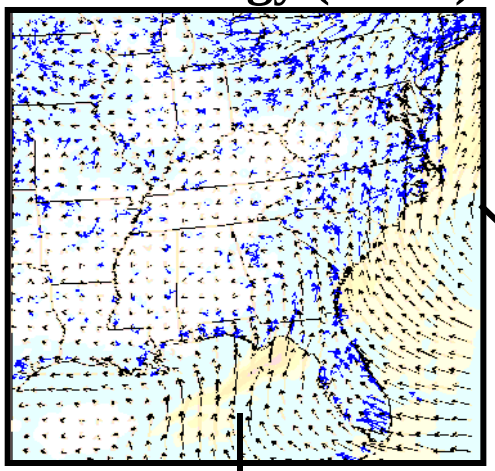


- **Hybrid Model**
  - Blending of Lagrangian parcels into Eulerian grids
  - CAMx and CMAQ with “plume-in-grid” treatments

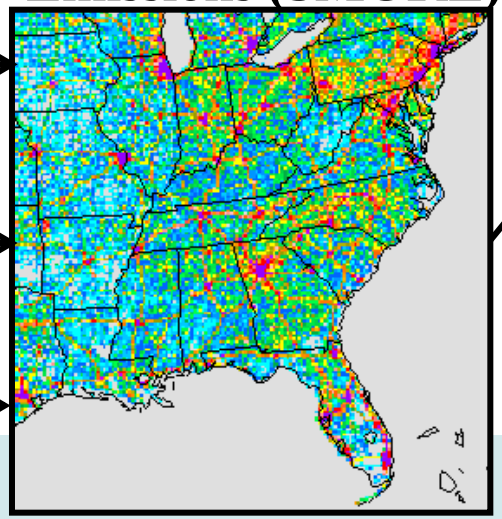


PGM MODELING SYSTEM

Meteorology (WRF)



Emissions (SMOKE)

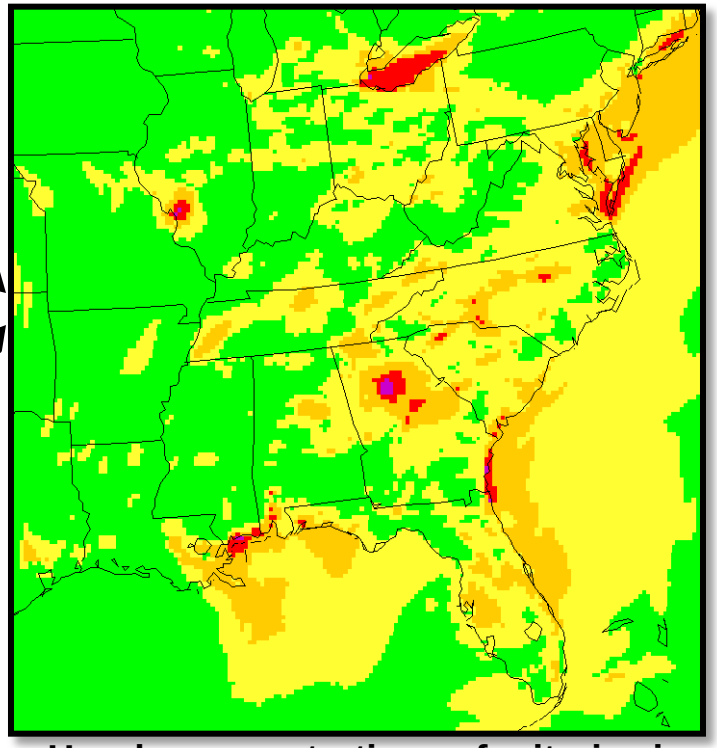


Biogenic Emissions

Emissions Inventory (NEI)

MOVES Rates

Air Quality (CMAQ/CAMx)



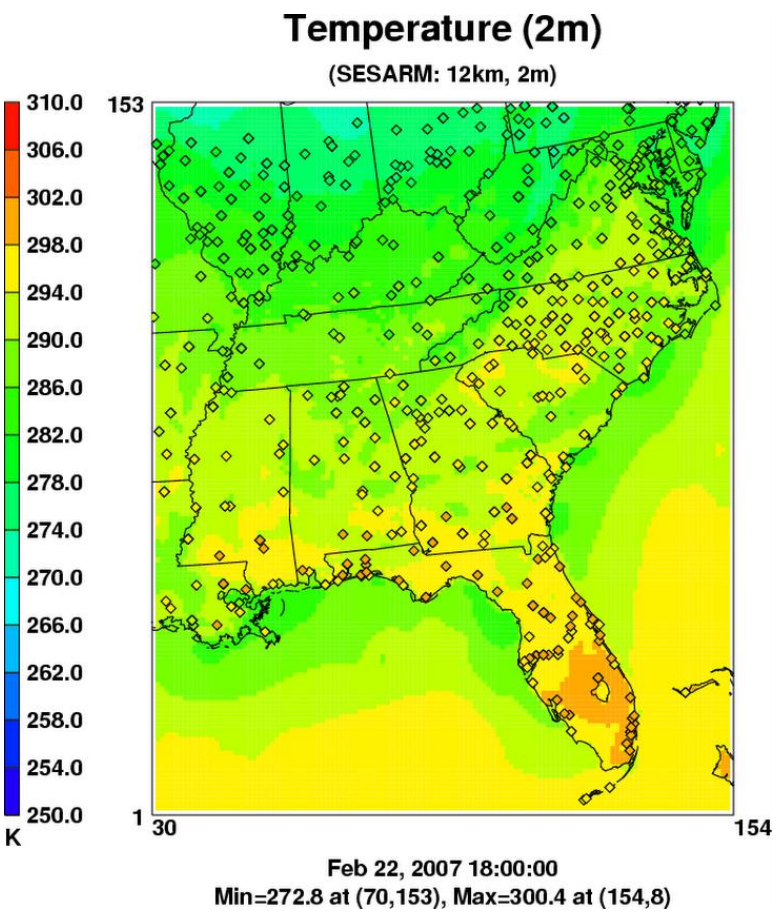
Hourly concentrations of criteria air pollutants and precursor pollutants

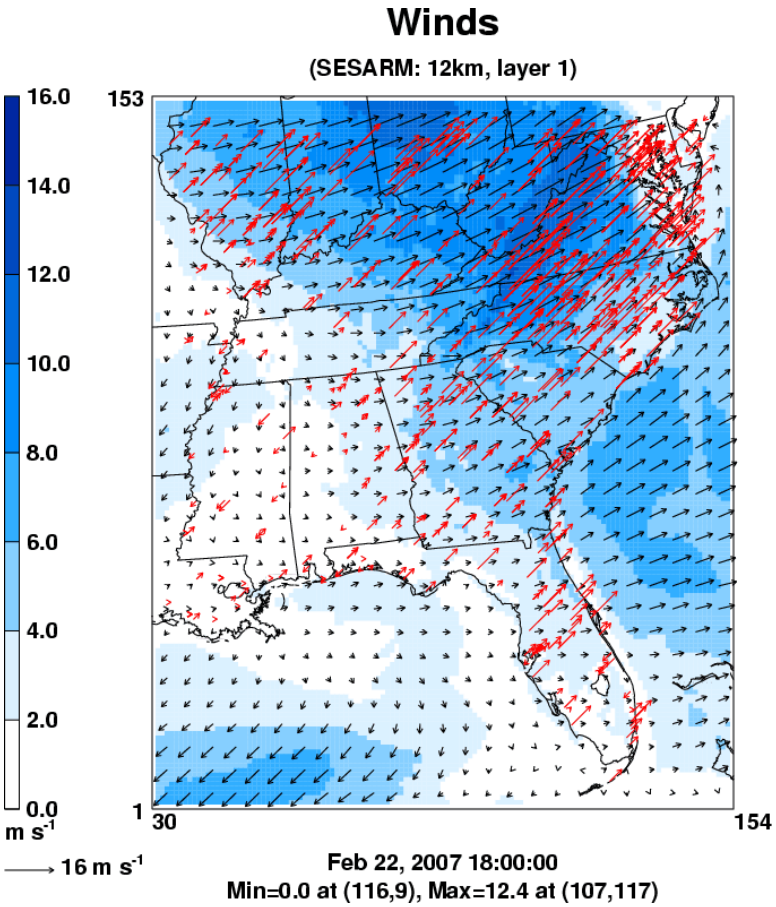
MODEL INPUTS

METEOROLOGY

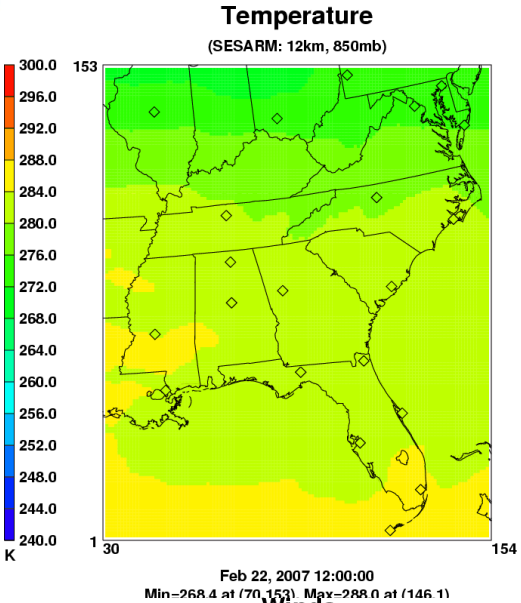
- **Meteorological data for PGMs is generated using prognostic Mesoscale Meteorological Models (e.g., MM5, WRF)**
  - Numerical model that solves coupled mass, energy, and momentum equations
- **Modeled Meteorological Parameters**
  - Air Temperature, Pressure, and Density
  - Wind Speed and Direction
  - Absolute and Relative Humidity
  - Precipitation and Cloud Parameters
  - Incoming Solar Radiation
  - Mixing Heights and Vertical Diffusivities

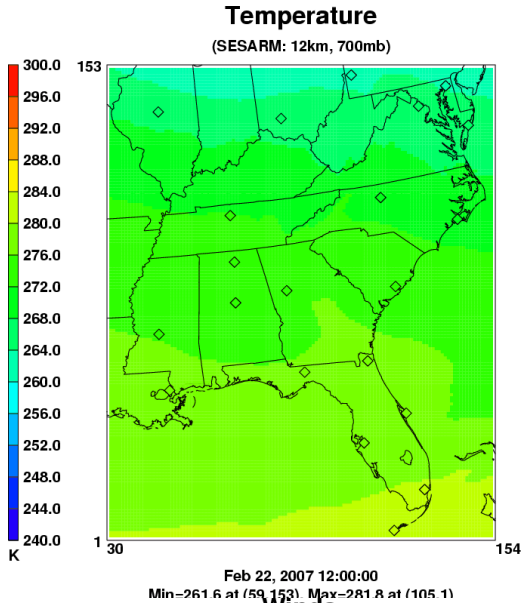
SURFACE PARAMETERS

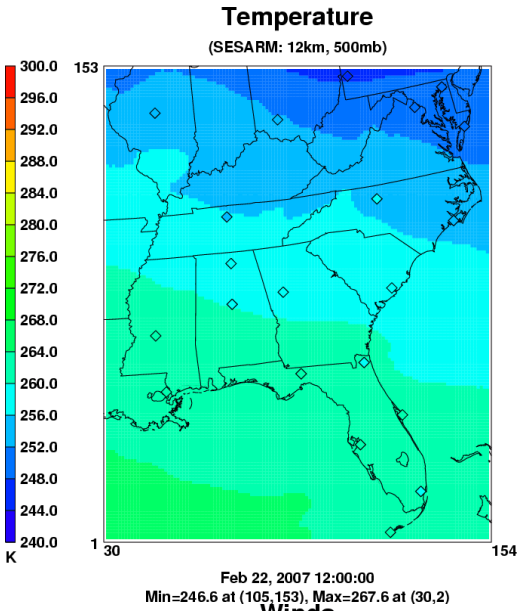


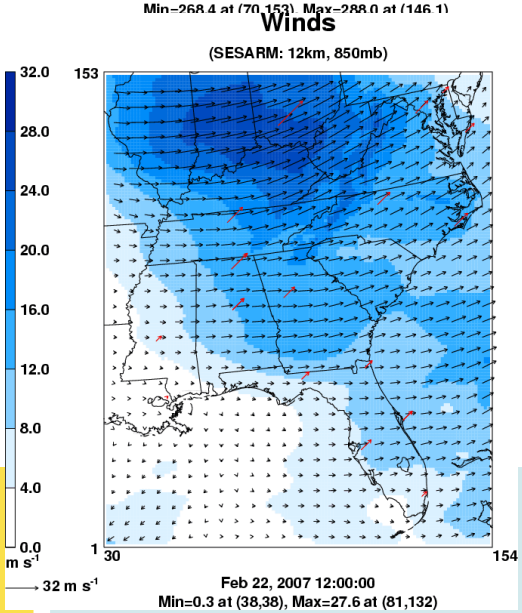


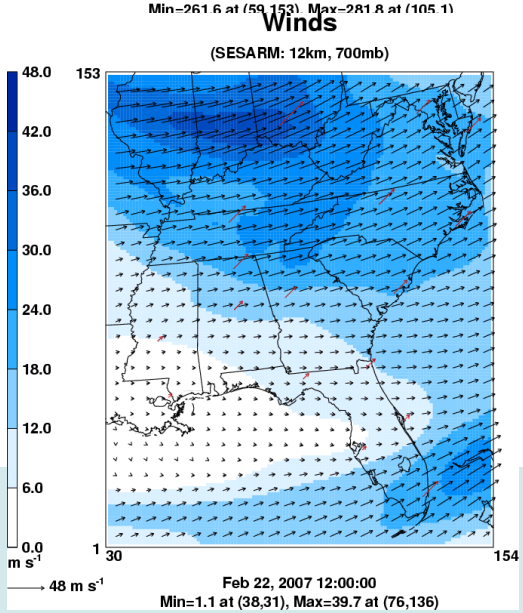
ALOFT PARAMETERS

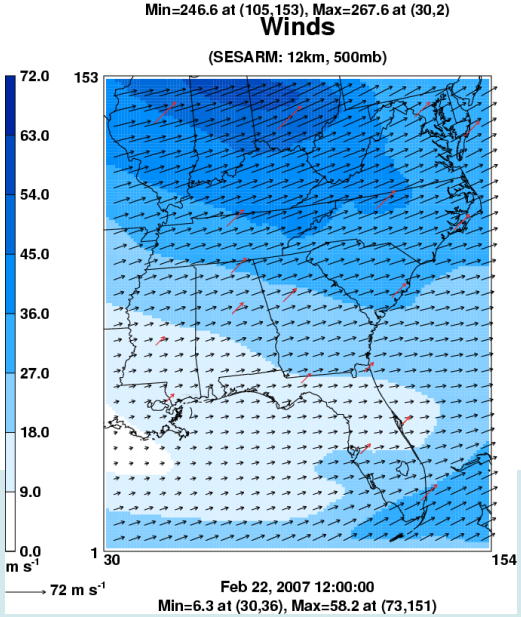












EMISSIONS INVENTORIES

Point

Area

On-road Mobile

Non-Road Mobile

Marine

Aircraft

Rail

Fires

Biogenics

MODELED EMISSION SPECIES

CB6 Chemical Mechanism

- 90 species, 227 reactions

Gas-Phase Species

- Volatile Organic Compounds (VOCs)
  - Methane, Ethane, Propane, Ethene, Propene, 1,3-Butadiene, Isoprene, Terpenes, Benzene, Toluene, o-Xylene, Formaldehyde, etc…
- Non-VOCs
  - CO, NO, NO_2, SO_2, NH_3, HNO_3, etc…

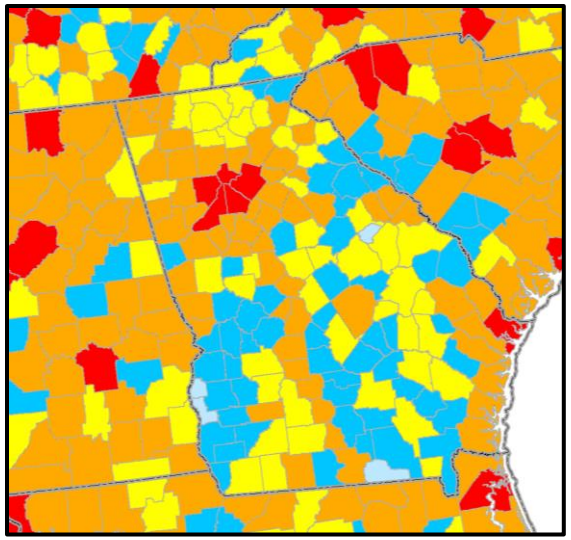
Aerosol Phase Species

- SO_4, NO_3, NH_4, OC, EC, Soils, CM, Sea Salt

SMOKE MODELING

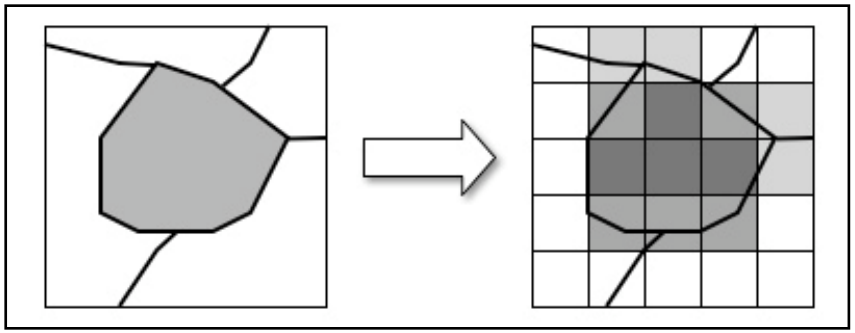
- Sparse Matrix Operator Kernel Emissions (SMOKE)
- Temporal Allocation
  - Annual ➔ monthly ➔ weekly ➔ daily ➔ hourly
- Spatial Allocation
  - County level ➔ grid cell level (e.g., 12-km)
  - Spatial surrogates (population, VMT, etc)
- Pollutant Speciation
  - NOx ➔ NO_2 and NO
  - VOCs ➔ Methane, Ethane, Propane, Ethene, Propene, 1,3-Butadiene, Isoprene, Terpenes, Benzene, Toluene, o-Xylene, Formaldehyde, etc…
  - $PM_{2.5}$ ➔ Sulfate, Nitrate, Organic Carbon, Elemental Carbon, etc…

EMISSIONS MODELING



Annual NOx emissions

+



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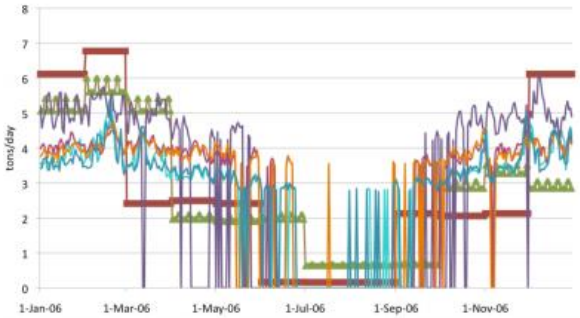
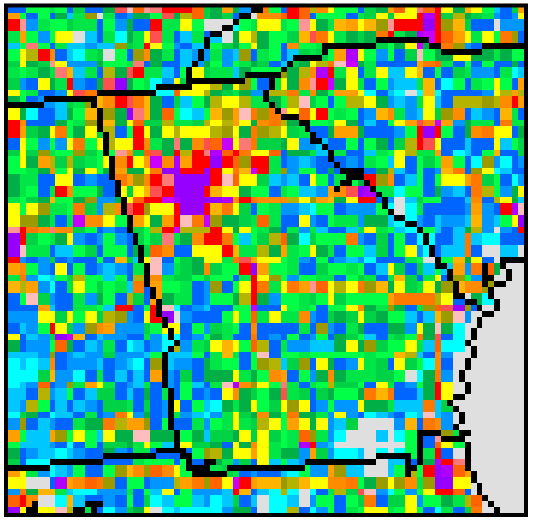


Annual ➔ Hourly

+

NO vs. NO_2

➔

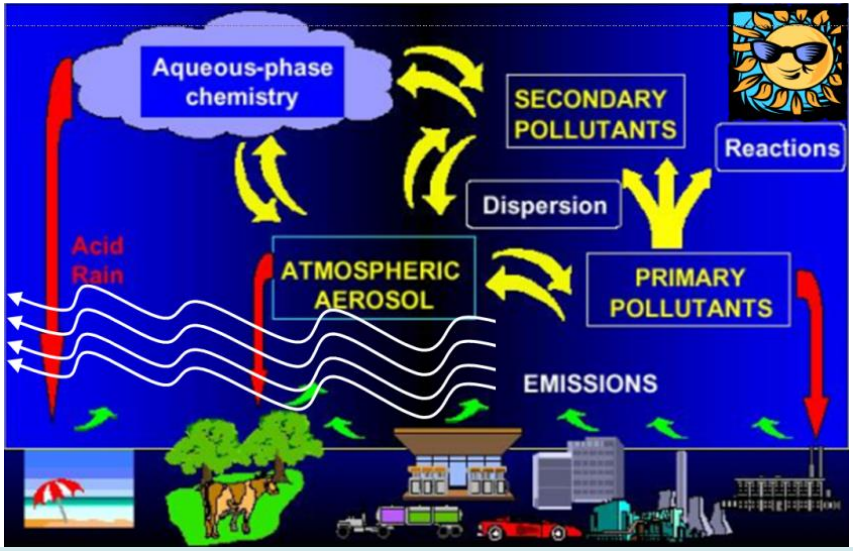


Hourly NO emissions

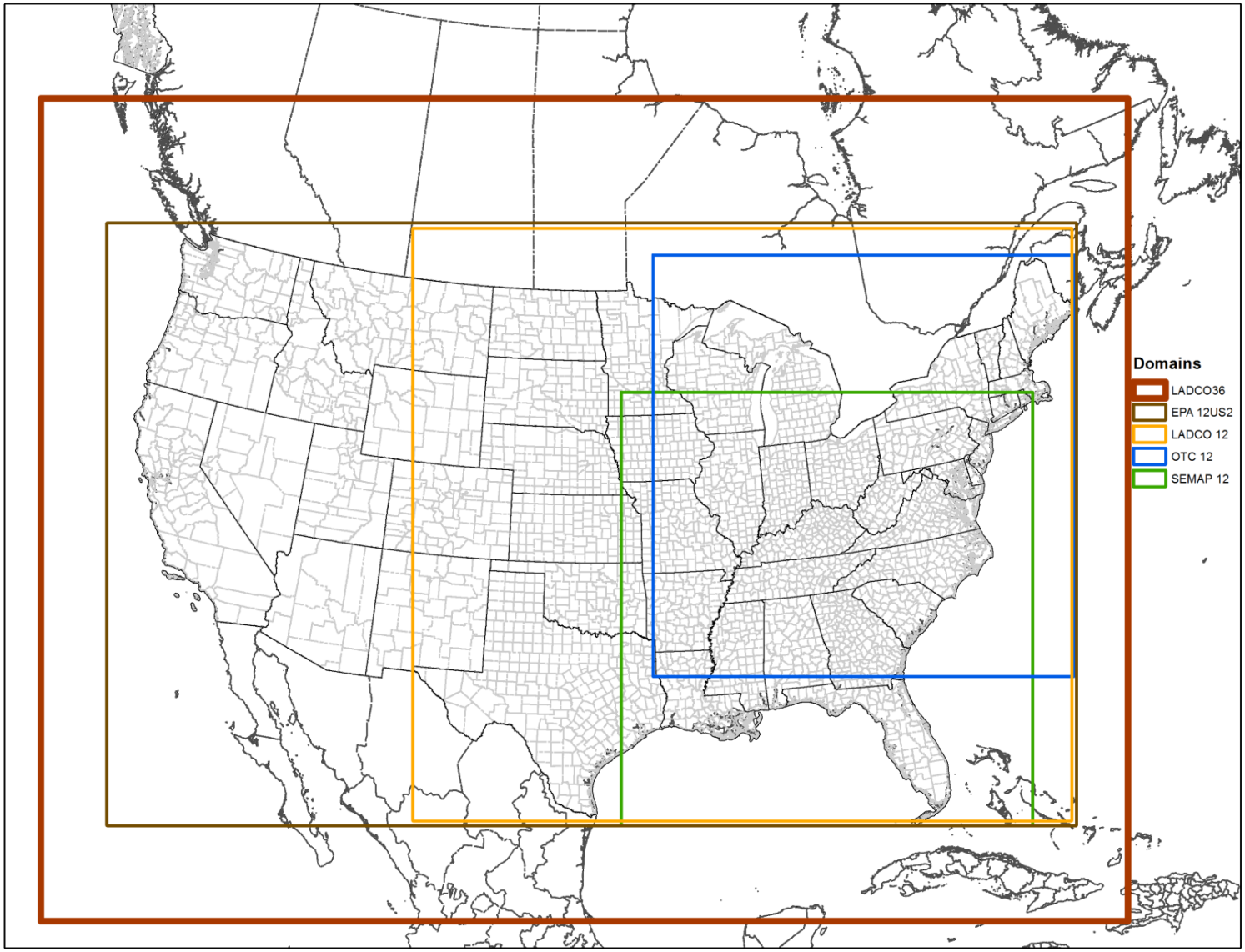
HOW PGMs WORK

PGM MODEL PROCESSES

- Emissions (source)
- Transport
  - Advection (transport by mean/resolved wind)
  - Turbulent diffusion (transport by unresolved motion)
- Chemical transformations (source and sink)
  - Gas-phase chemistry
  - Aerosol dynamics
  - Heterogeneous chemistry
- Deposition (sink)
  - Wet deposition
  - Dry deposition



EXAMPLE MODELING DOMAINS



INSTANTLY MIXED GRID CELLS

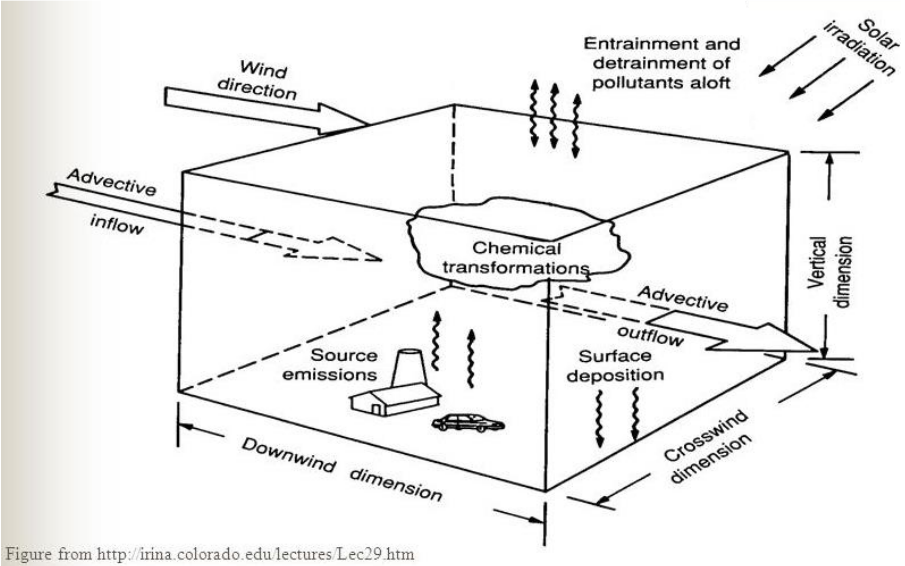
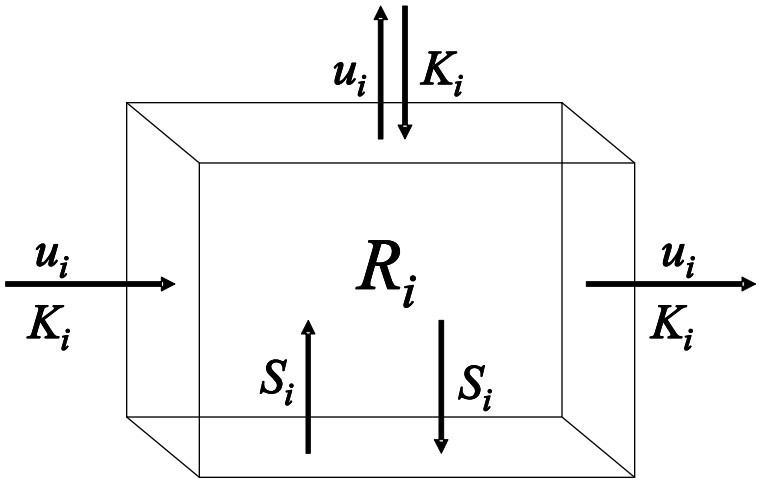
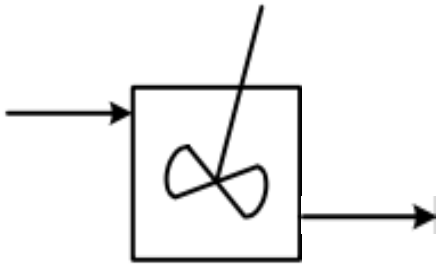


Figure from http://irina.colorado.edu/lectures/Lec29.htm



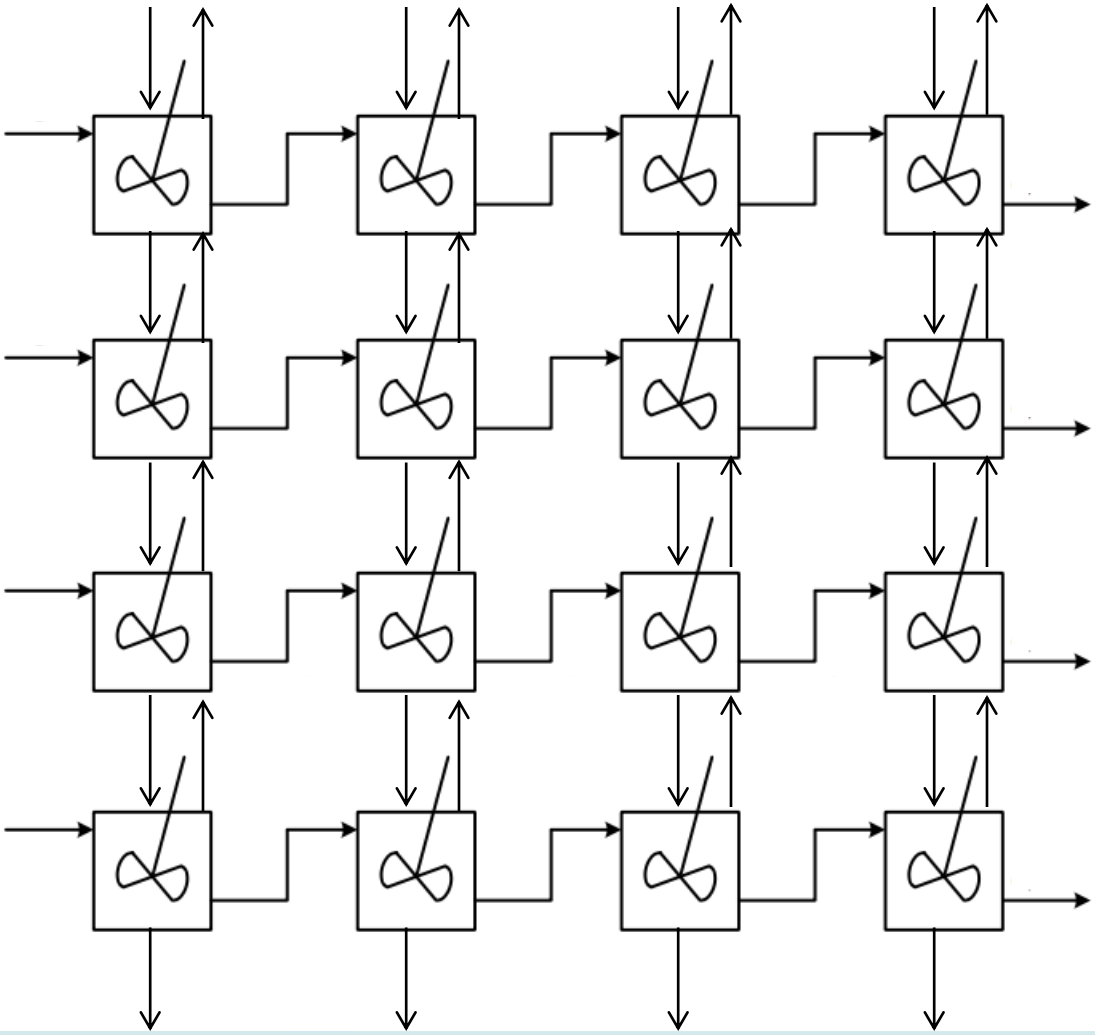
Well-mixed reactor cell



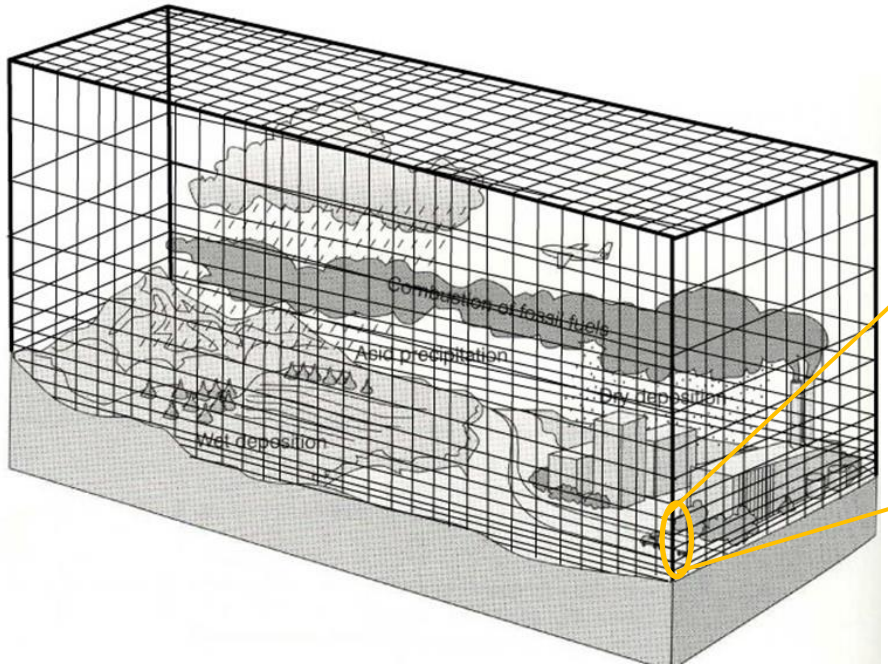
Atmospheric Diffusion Equation

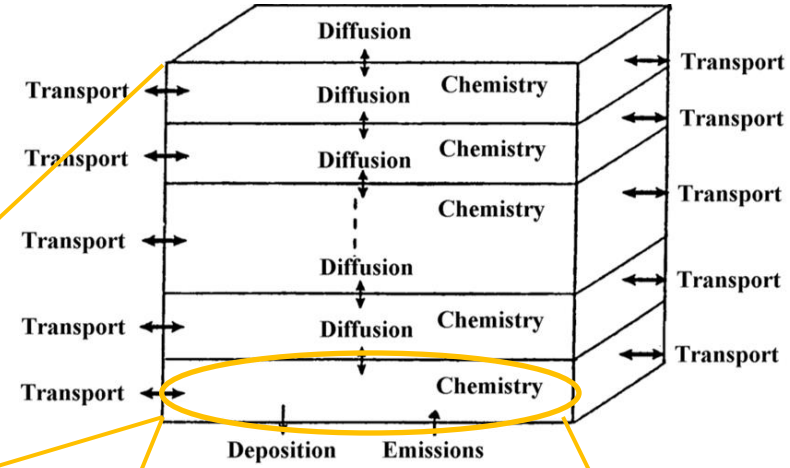
$$\frac{\partial c_i}{\partial t} + \nabla \cdot (\mathbf{u}\, c_i) = \nabla \cdot (\mathbf{K}\, \nabla c_i) + R_i + S_i$$

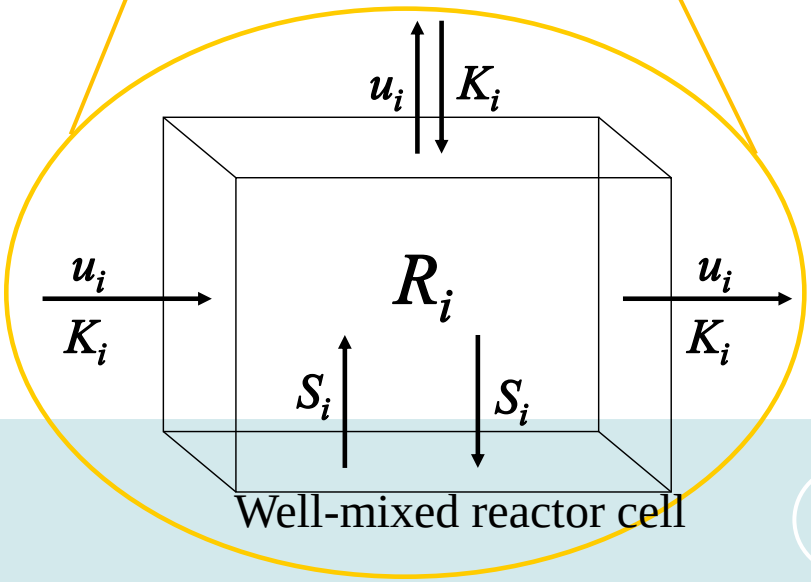
SERIES OF MIXED REACTORS



PHOTOCHEMICAL GRID MODELS



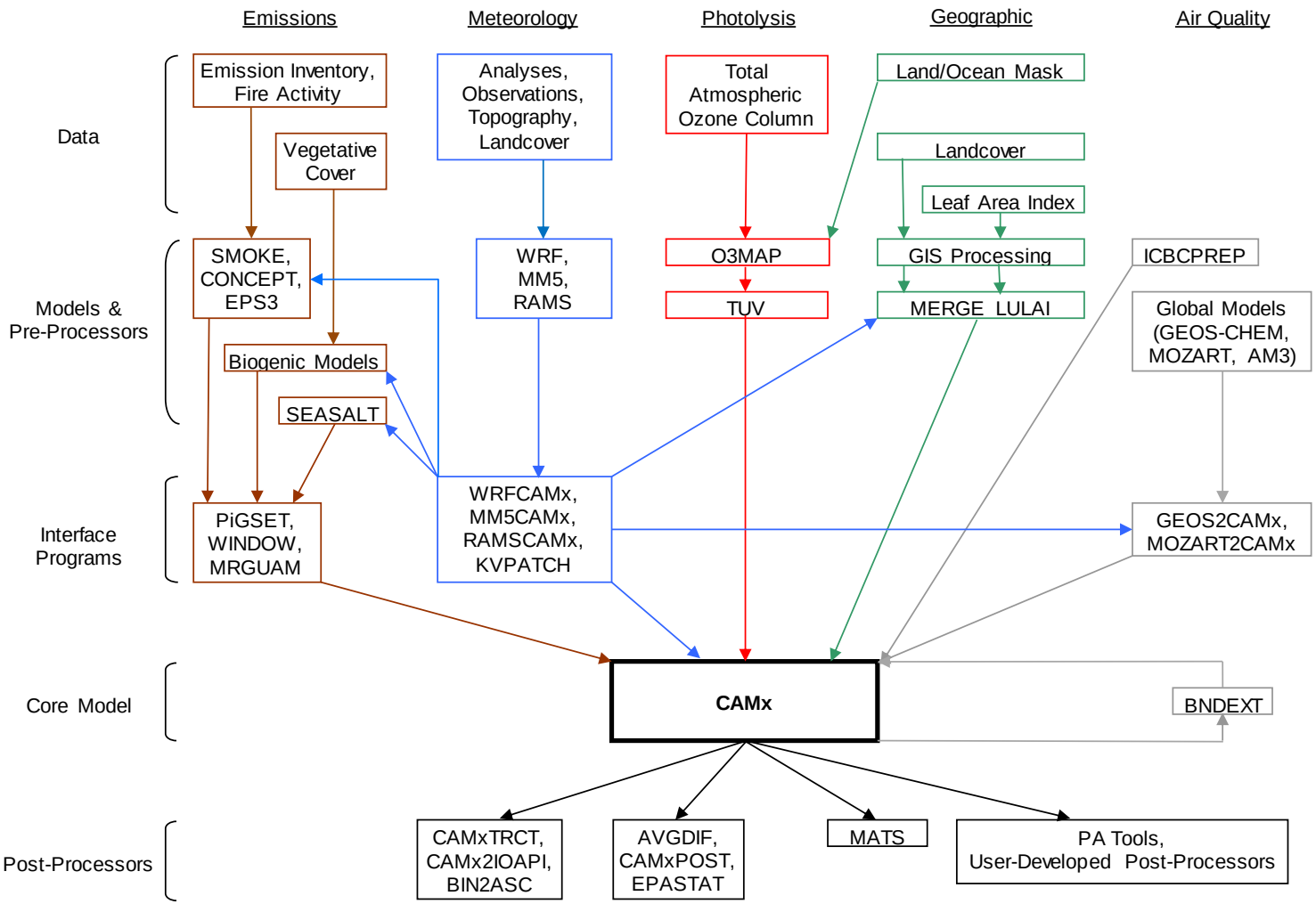




Atmospheric Diffusion Equation

$$\frac{\partial c_i}{\partial t} + \nabla \cdot (\mathbf{u}\, c_i) = \nabla \cdot (\mathbf{K}\, \nabla c_i) + R_i + S_i$$

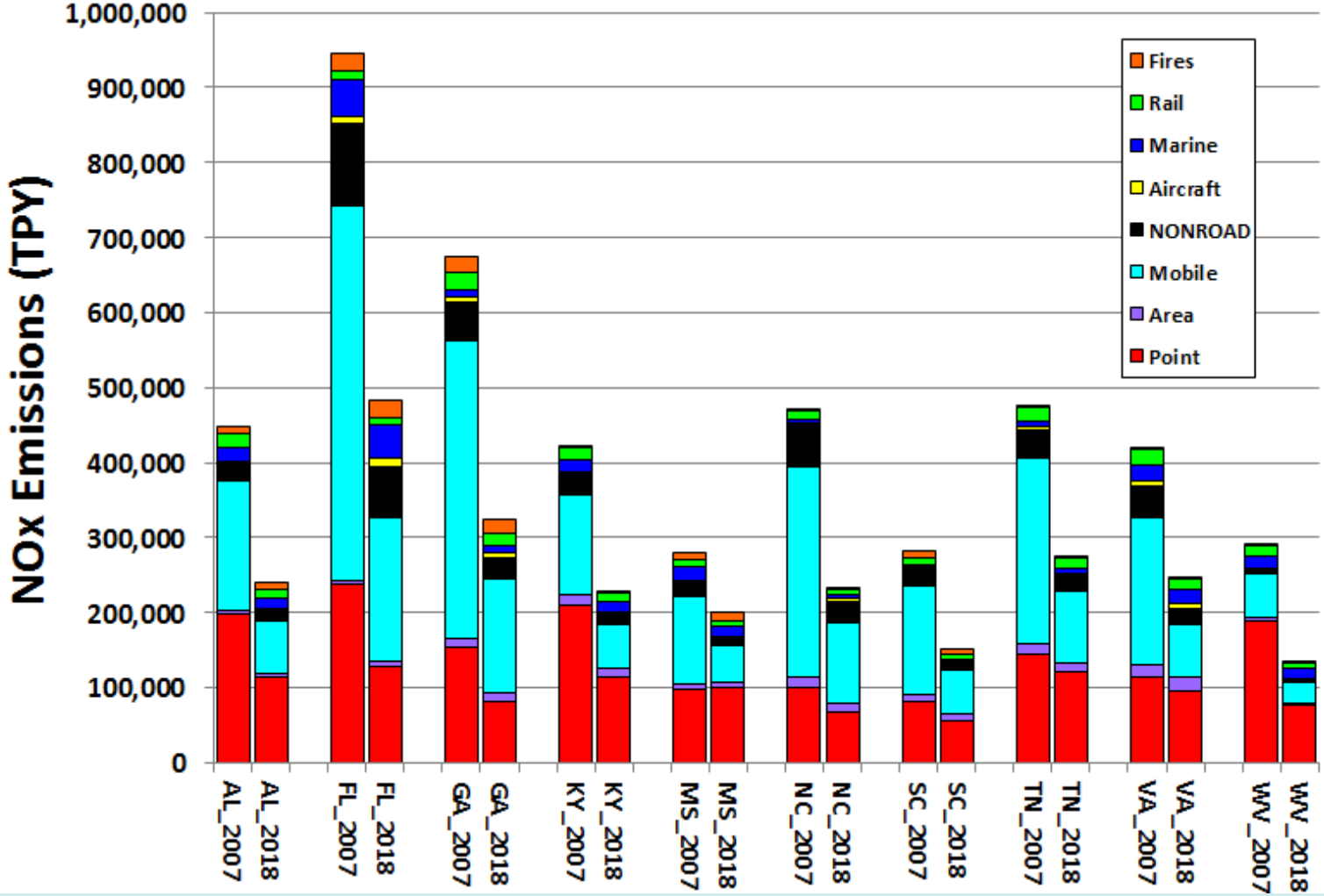
CAMx MODELING SYSTEM



File Formatting | Performance | Regulatory | Probing Tools

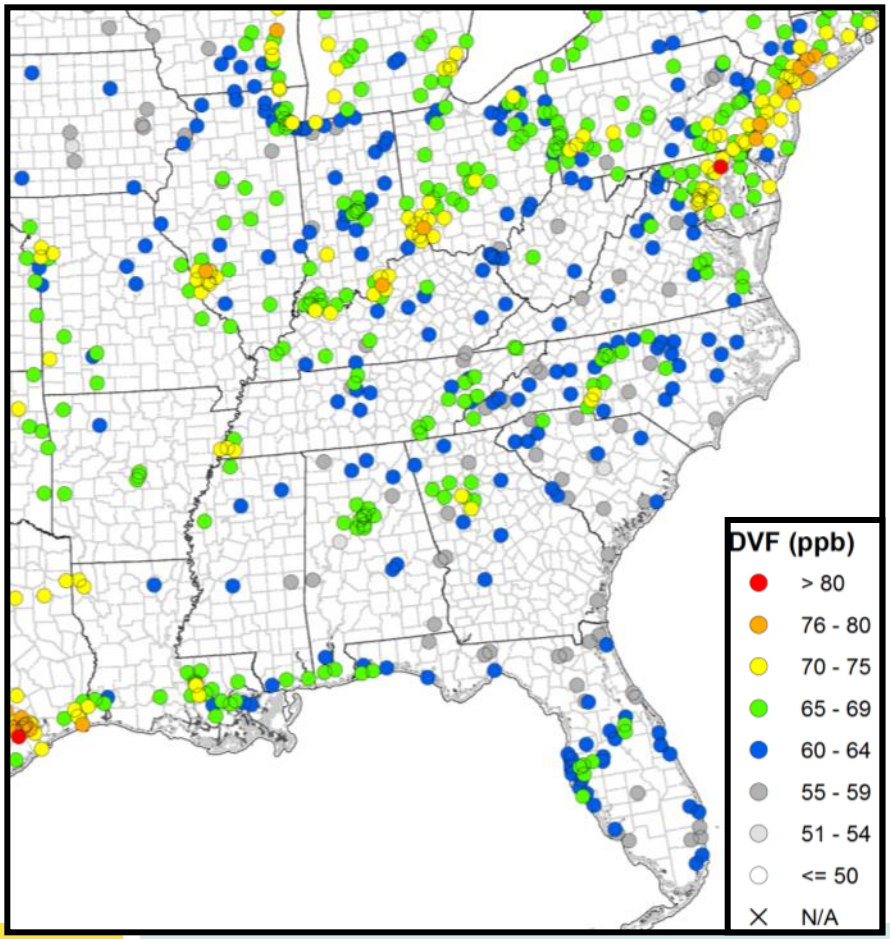
RAMBOLL ENVIRON

NO_X EMISSION PROJECTIONS

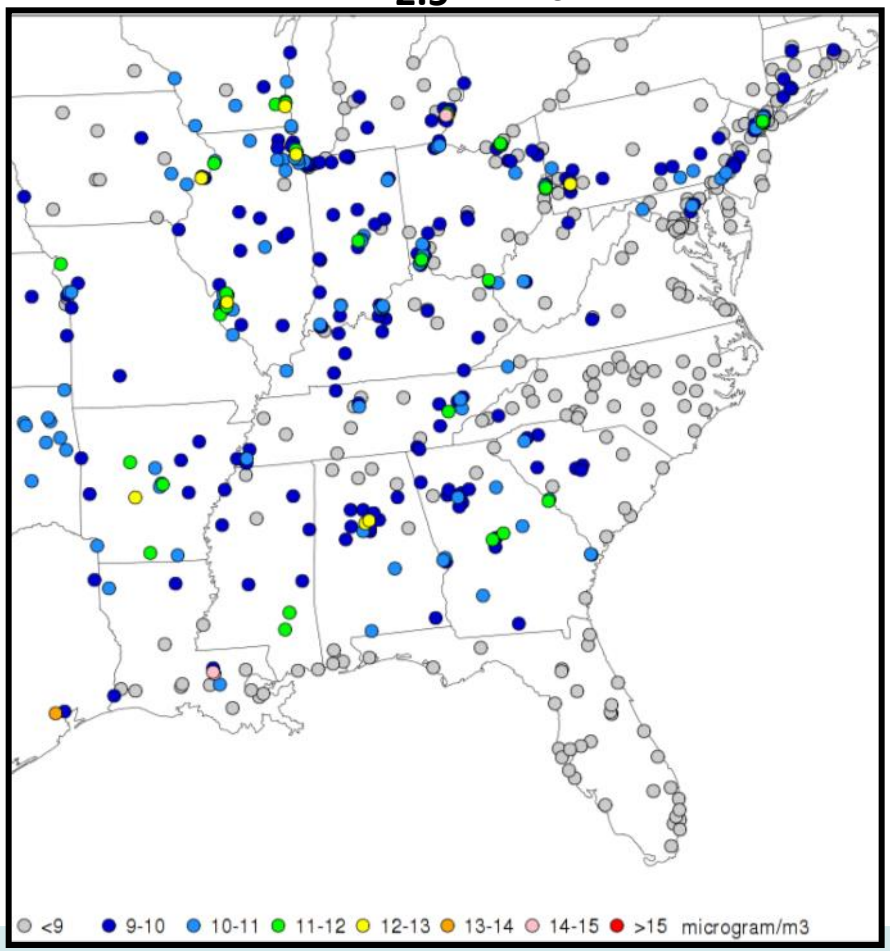


2018 PROJECTIONS

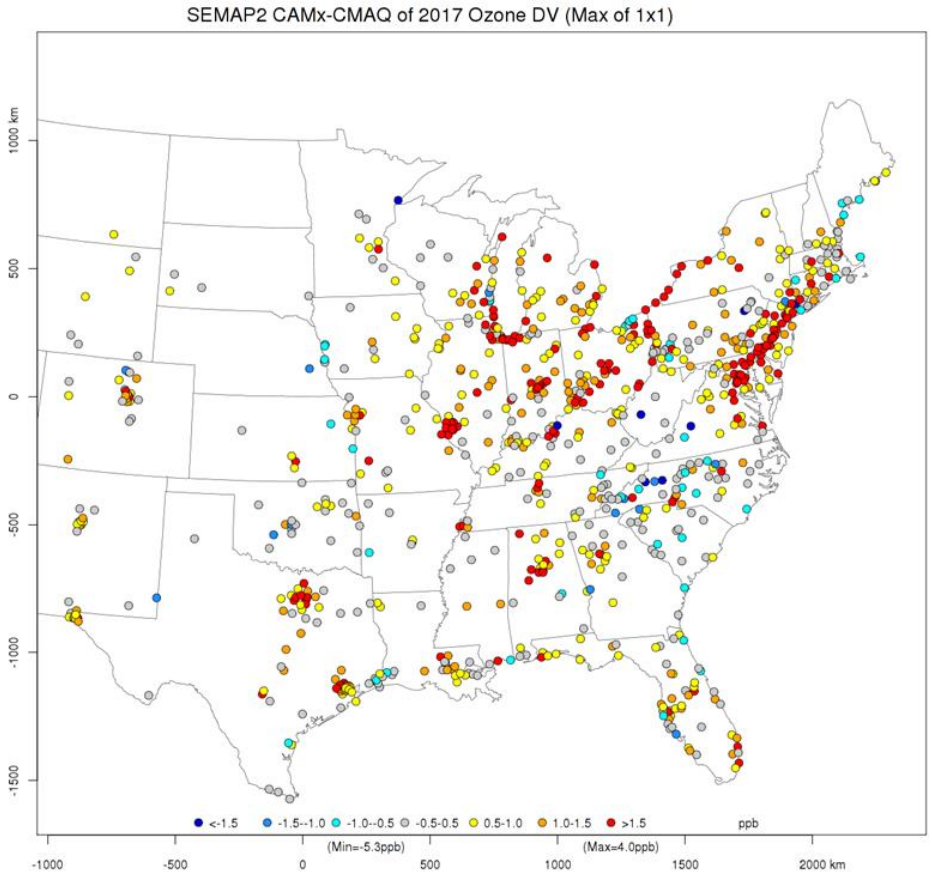
2018 Ozone Projections

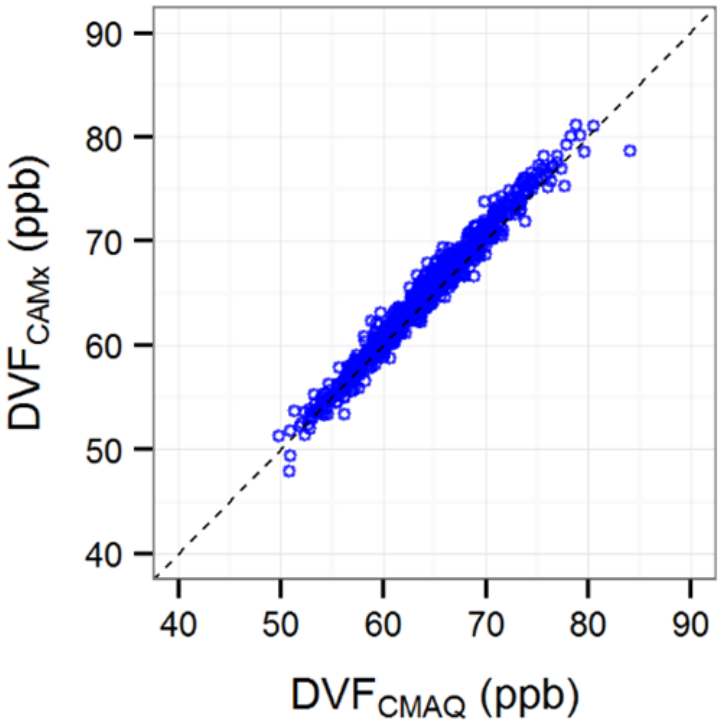


2018 $PM_{2.5}$ Projections

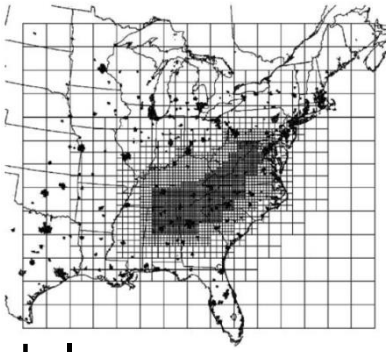


CAMx vs. CMAQ

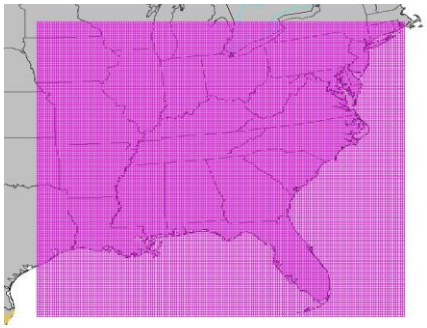

SEMAP2 CAMx-CMAQ of 2017 Ozone DV (Max of 1x1)
1000 km
500
0
-500
-1000
-1500
<-1.5
-1.5--1.0
-1.0--0.5
-0.5-0.5
0.5-1.0
1.0-1.5
>1.5
ppb
(Min=-5.3ppb)
(Max=4.0ppb)
-1000
-500
0
500
1000
1500
2000 km


DVF$_{CAMx}$ (ppb)
DVF$_{CMAQ}$ (ppb)
40
50
60
70
80
90

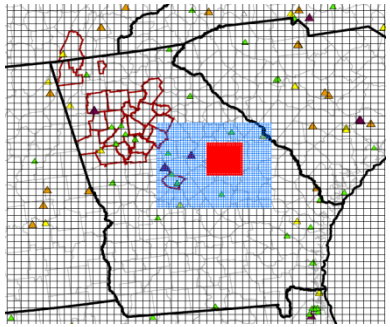
EVOLUTION OF PGMs



- **CIT ➔ URM ➔ URM-1ATM**
  - CIT = California/Carnegie Institute of Technology Model
  - URM = Urban-to-Regional Multiscale Model
  - URM-1ATM = Urban-to-Regional Multiscale - One Atmosphere Model (Boylan, 2002)



- **MAQSIP ➔ CMAQ**
  - MAQSIP = Multiscale Air Quality Simulation Platform
  - CMAQ = Community Multiscale Air Quality Model

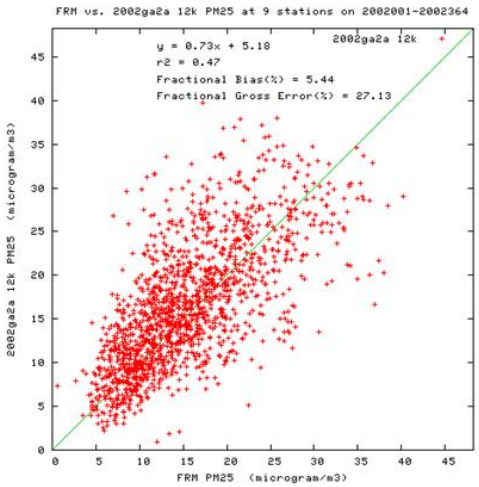


- **UAM ➔ UAM-V ➔ CAMx**
  - UAM = Urban Airshed Model
  - UAM-V = Variable-Grid Urban Airshed Model
  - CAMx = Comprehensive Air Quality Model with Extensions

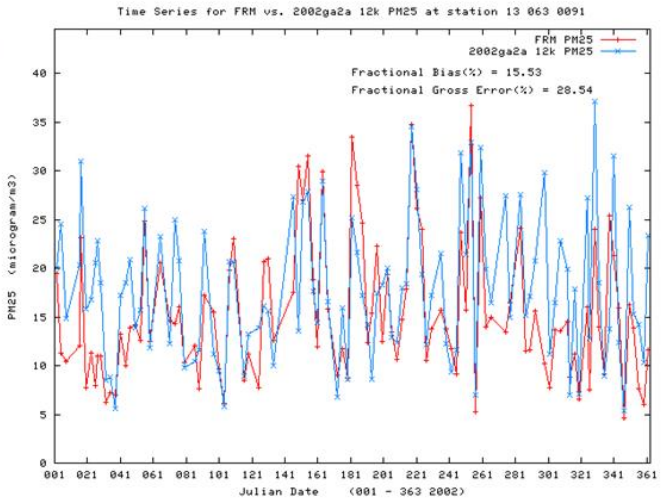
MODEL PERFORMANCE EVALUATION

“All models are wrong. Some are useful.”

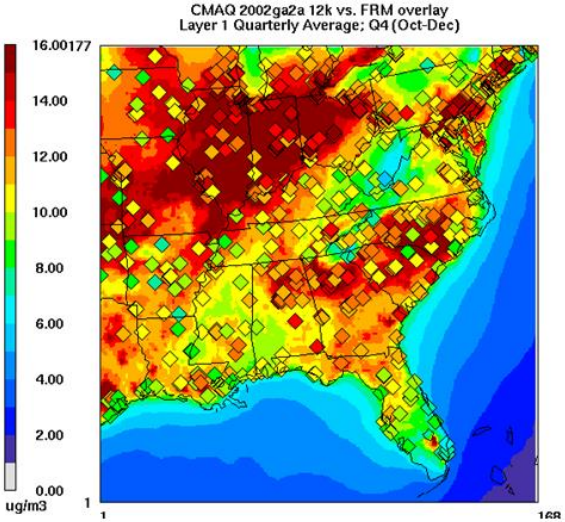
COMMON MPE PLOTS



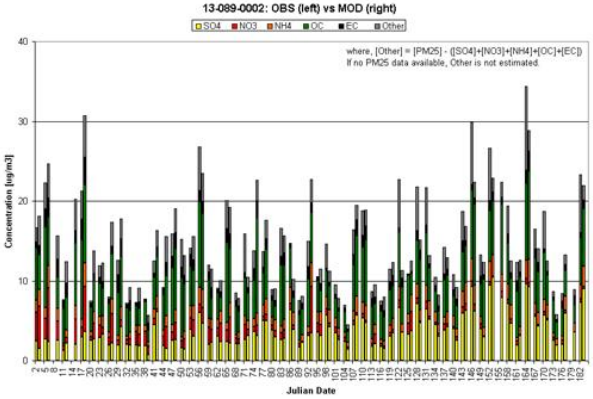
(a)



(b)



(c)



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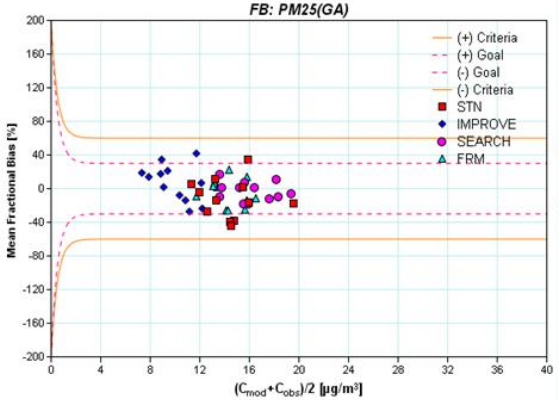
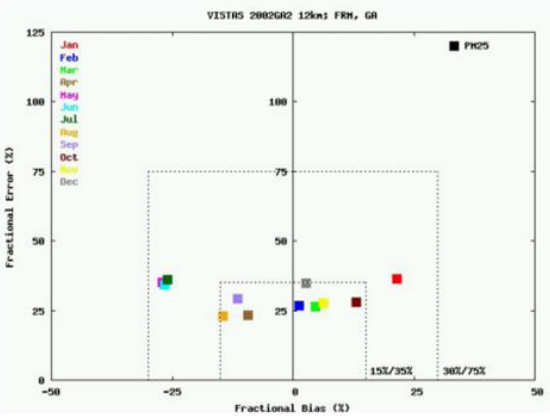


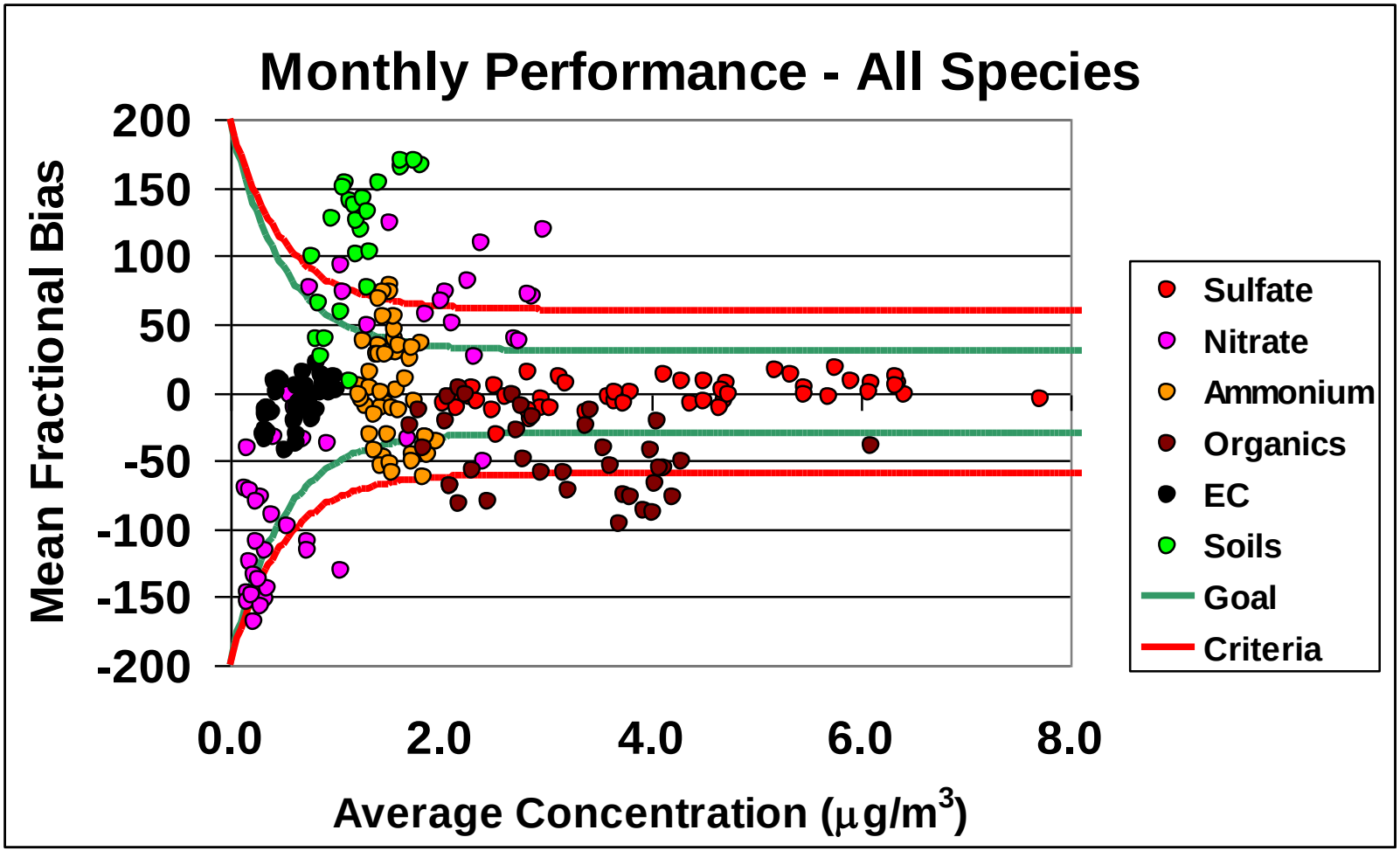
(e)



(f)

Russell A., **Boylan J.**, Napelenok S. (2012) Air Pollution Data for Model Evaluation and Application. *EM*, May 2012, pp. 30-35.

$PM_{2.5}$ MODEL PERFORMANCE

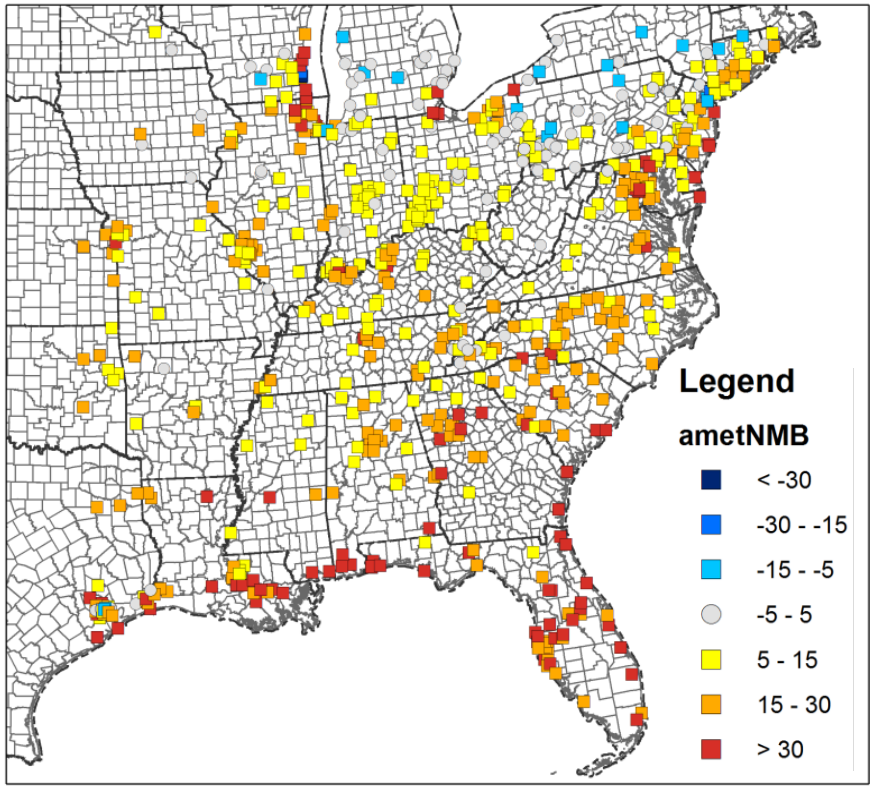


Boylan, J.W. and Russell, A.G. (2006). PM and Light Extinction Model Performance Metrics, Goals, and Criteria for Three-Dimensional Air Quality Models; *Atmos. Environ.*, Volume 40, pp. 4946-4959.

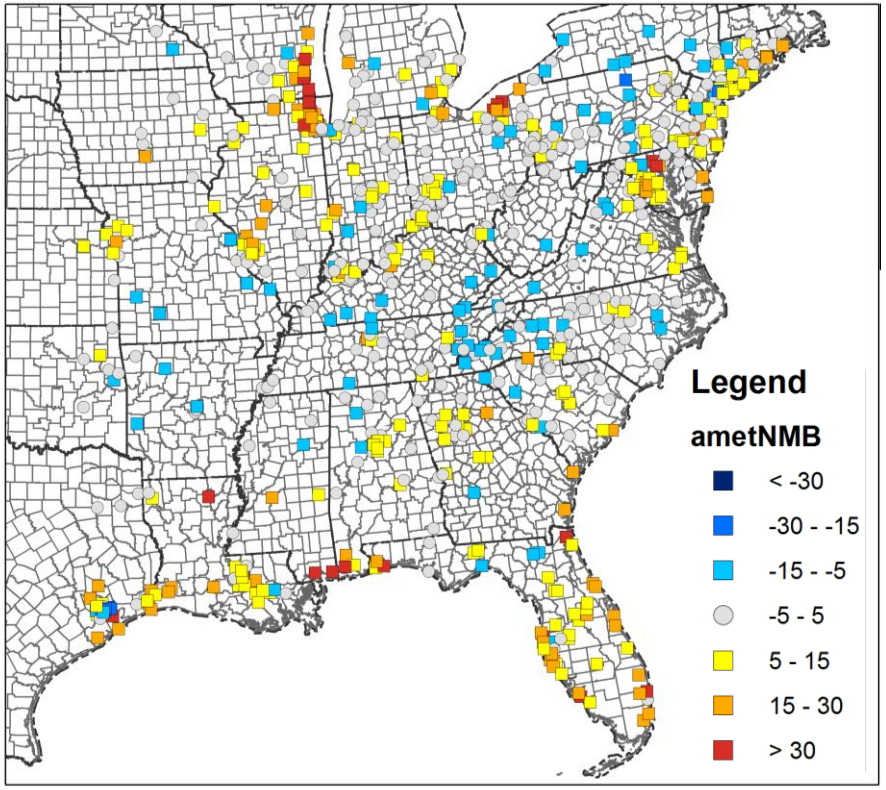
Emery, C., Liu, Z., Russell, A. G., Odman, M. T., Yarwood, G., & Kumar, N. (2017). Recommendations on Statistics and Benchmarks to Assess Photochemical Model Performance. *Journal of the Air & Waste Management Association*, 67(5), 582-598. doi:10.1080/10962247.2016.1265027.

8-HOUR OZONE NMB - AUGUST

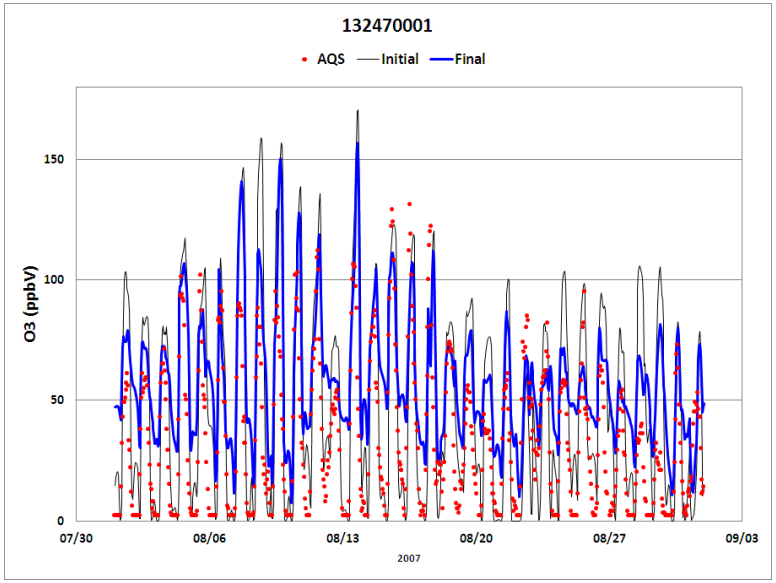
BEFORE

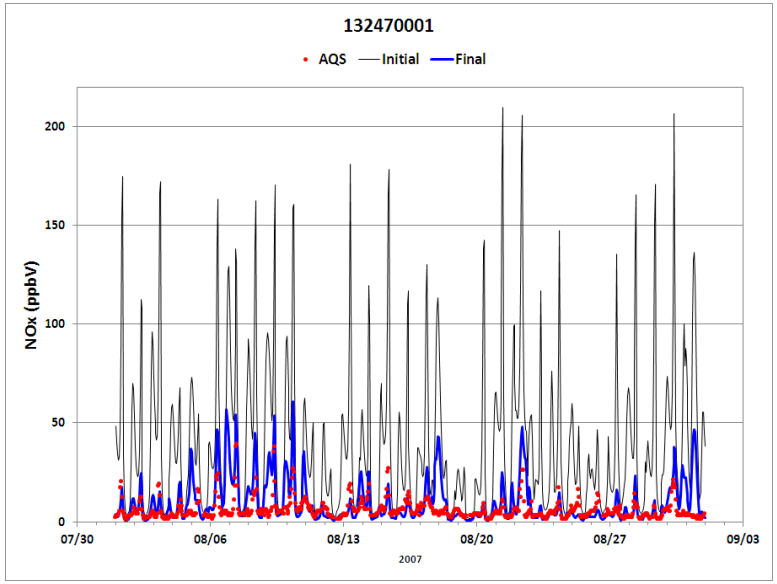


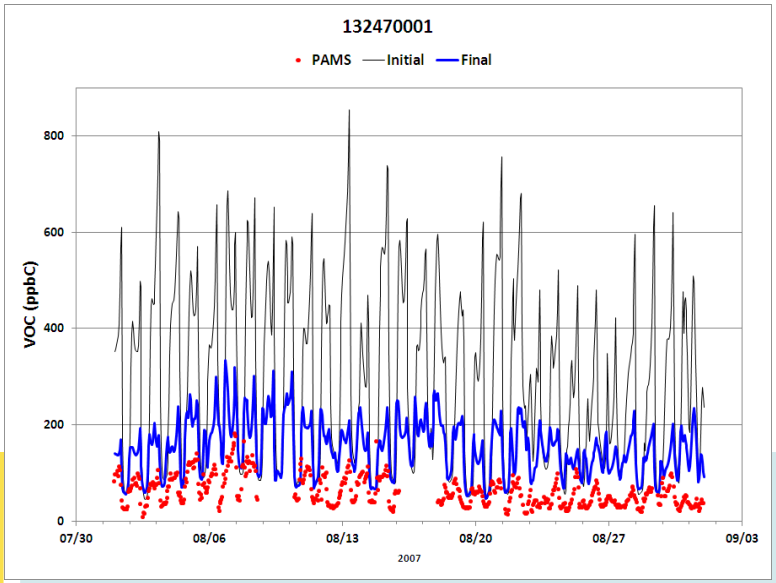
AFTER

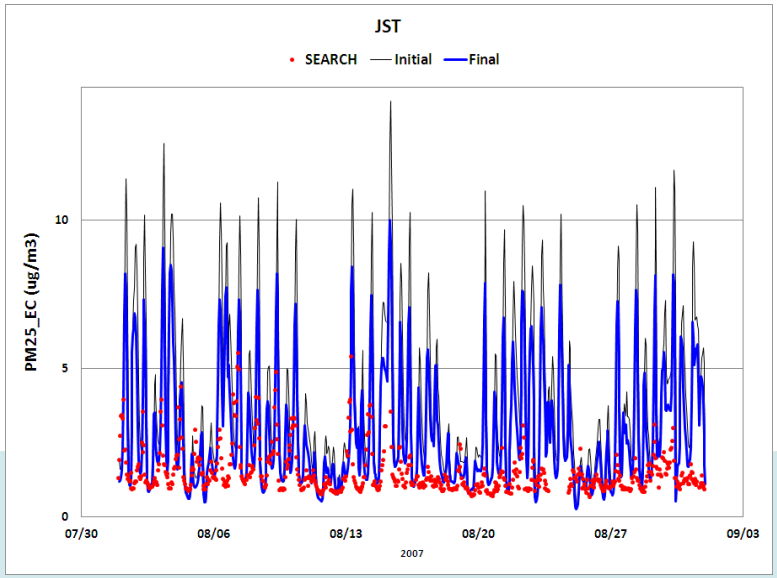


TIME SERIES PLOTS - AUGUST





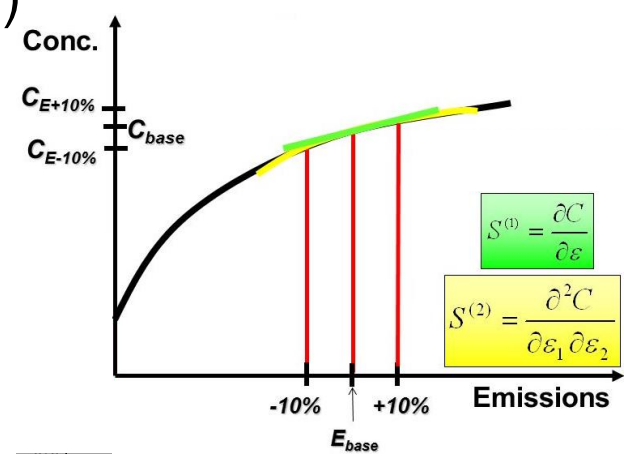




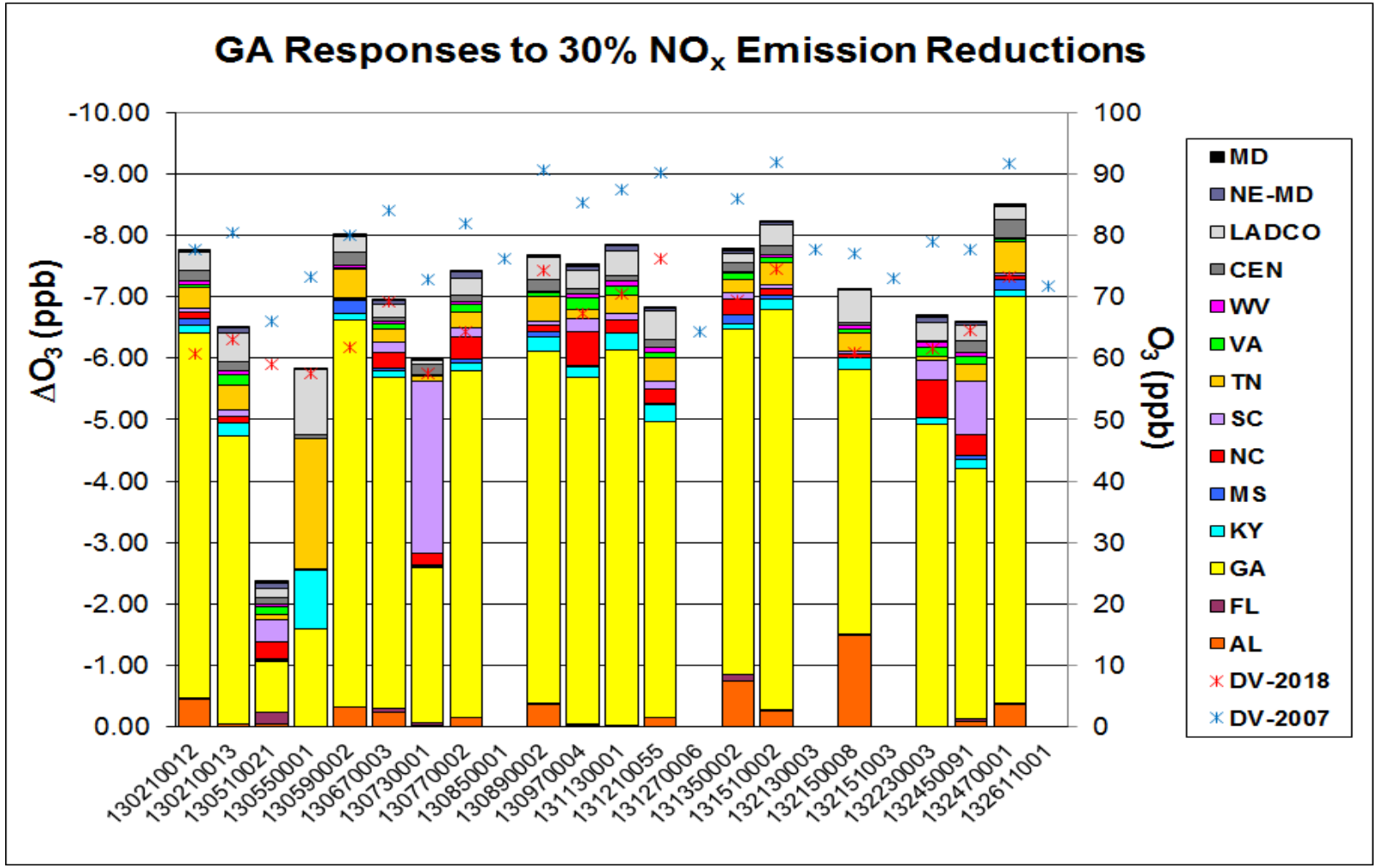
PROBING TOOLS

COMMON PROBING TOOLS

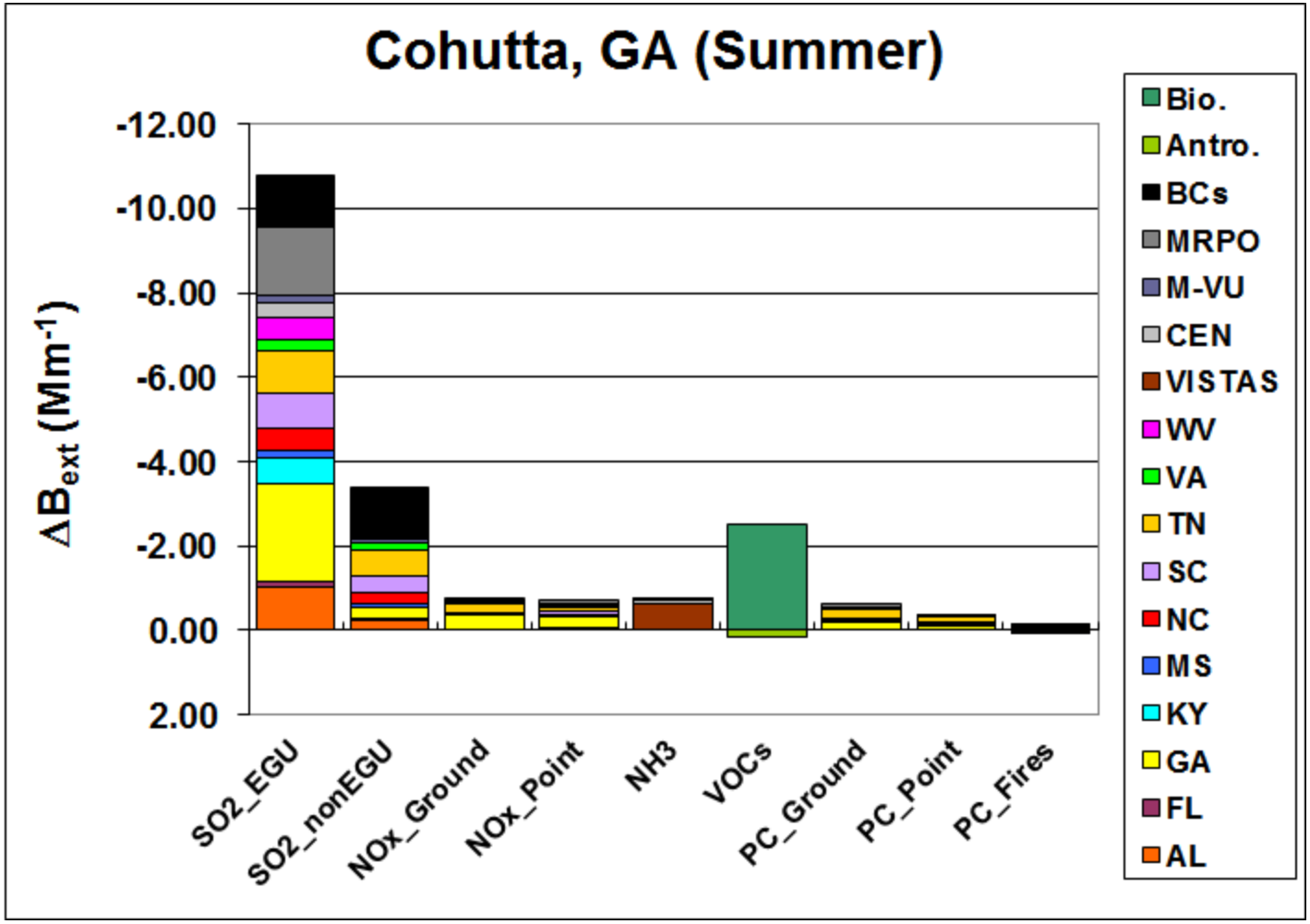
- Sensitivity vs. Source Apportionment
- Brute Force Sensitivity
  - ±10%, ±30%, ±50%, ±100%
- Source Apportionment Tagging
  - CAMx ➔ PSAT ($PM_{2.5}$), OSAT/APCA (ozone)
  - CMAQ ➔ ISAM ($PM_{2.5}$ and ozone)
- Decoupled Direct Method
  - First order (DDM)
  - Higher Order (HDDM)
  - Ozone and $PM_{2.5}$



2018 EMISSION SENSITIVITIES



EMISSION SENSITIVITIES



EPA PROPOSED CSAPR CONTRIBUTIONS

Monitor ID	State	County	2017 Projected Average Design Value	2017 Projected Maximum Design Value	AL	FL	GA	KY	MS	NC	SC	TN	VA	WV
480391004	Texas	Brazoria	81.4	82.3	0.56	0.19	0.30	0.18	0.78	0.08	0.08	0.37	0.04	0.03
240251001	Maryland	Harford	81.3	84.0	0.40	0.11	0.30	1.97	0.15	0.46	0.10	0.70	5.29	2.99
484392003	Texas	Tarrant	79.6	82.1	0.79	0.34	0.47	0.22	0.54	0.09	0.10	0.21	0.03	0.04
361030002	New York	Suffolk	79.2	80.8	0.19	0.06	0.19	0.71	0.11	0.38	0.08	0.35	1.62	0.98
482011039	Texas	Harris	78.2	80.2	0.41	0.15	0.21	0.09	0.77	0.06	0.05	0.31	0.03	0.02
90019003	Connecticut	Fairfield	78.0	81.1	0.14	0.04	0.19	0.57	0.09	0.47	0.14	0.28	1.75	0.95
90099002	Connecticut	New Haven	77.2	80.2	0.09	0.04	0.10	0.43	0.06	0.38	0.07	0.18	1.22	0.66
90013007	Connecticut	Fairfield	77.1	81.4	0.15	0.02	0.20	0.48	0.09	0.55	0.16	0.31	1.87	0.92
390610006	Ohio	Hamilton	76.3	79.1	0.79	0.11	0.58	11.17	0.30	0.13	0.14	1.67	0.11	0.97
360850067	New York	Richmond	76.3	77.8	0.25	0.09	0.30	0.96	0.11	0.55	0.14	0.42	2.27	1.64
211110067	Kentucky	Jefferson	75.8	78.6	0.04	0.03	0.04	22.87	0.04	0.01	0.01	0.11	0.01	0.61
90010017	Connecticut	Fairfield	75.8	78.4	0.10	0.03	0.11	0.35	0.07	0.33	0.07	0.17	1.51	0.67
360810124	New York	Queens	75.7	77.6	0.13	0.08	0.20	0.49	0.06	0.39	0.11	0.16	2.10	0.92
482010055	Texas	Harris	75.4	77.0	1.28	0.64	0.56	0.19	1.48	0.16	0.15	0.41	0.06	0.05
420031005	Pennsylvania	Allegheny	75.3	76.5	0.16	0.06	0.17	1.64	0.13	0.07	0.05	0.62	0.16	2.47
421010024	Pennsylvania	Philadelphia	75.1	78.4	0.51	0.14	0.54	2.14	0.17	0.72	0.20	0.90	2.63	3.11
340150002	New Jersey	Gloucester	75.1	77.5	0.34	0.14	0.33	1.23	0.13	0.33	0.07	0.38	3.33	2.35
340071001	New Jersey	Camden	74.2	78.1	0.32	0.07	0.15	0.93	0.26	0.07	0.04	0.25	0.32	1.07
340290006	New Jersey	Ocean	73.9	76.6	0.21	0.05	0.17	0.88	0.12	0.33	0.09	0.40	1.07	1.08
211850004	Kentucky	Oldham	73.7	77.3	0.06	0.03	0.04	20.93	0.10	0.02	0.02	0.11	0.00	0.40
240053001	Maryland	Baltimore	73.2	76.2	0.34	0.10	0.27	1.77	0.13	0.93	0.14	0.67	4.70	2.65
340230011	New Jersey	Middlesex	73.0	76.3	0.28	0.09	0.31	1.08	0.10	0.50	0.12	0.48	2.10	1.91

Nonattainment

Maintenance

Significant impact

Self impact

SEMAP CAMx APCA 1x1 CONTRIBUTIONS

Monitor ID	State	County	2017 Projected Average Design Value	2017 Projected Maximum Design Value	AL	FL	GA	KY	MS	NC	SC	TN	VA	WV
484392003	Texas	Tarrant	81.0	83.5	0.81	0.35	0.48	0.22	0.55	0.09	0.11	0.22	0.04	0.05
480391004	Texas	Brazoria	81.0	82.0	0.58	0.19	0.30	0.18	0.79	0.09	0.09	0.39	0.05	0.03
240251001	Maryland	Harford	79.5	82.1	0.40	0.11	0.32	1.85	0.14	0.52	0.13	0.61	5.24	3.04
211110067	Kentucky	Jefferson	79.3	79.3	0.06	0.04	0.05	23.67	0.05	0.02	0.02	0.13	0.02	0.65
361030002	New York	Suffolk	79.2	80.8	0.20	0.06	0.20	0.73	0.12	0.39	0.09	0.36	1.64	1.02
90010017	Connecticut	Fairfield	79.0	81.6	0.10	0.03	0.12	0.36	0.07	0.33	0.08	0.17	1.47	0.67
390610006	Ohio	Hamilton	77.7	80.5	0.83	0.12	0.61	11.45	0.32	0.15	0.16	1.79	0.12	1.01
551170006	Wisconsin	Sheboygan	77.4	79.9	0.36	0.12	0.15	1.00	0.69	0.09	0.05	0.76	0.11	0.28
90013007	Connecticut	Fairfield	77.0	81.3	0.25	0.04	0.27	0.64	0.18	0.53	0.17	0.45	1.67	0.93
482011039	Texas	Harris	77.0	78.9	0.42	0.15	0.22	0.09	0.78	0.07	0.06	0.33	0.04	0.02
90019003	Connecticut	Fairfield	76.6	79.6	0.15	0.05	0.19	0.57	0.09	0.48	0.15	0.29	1.75	0.97
90099002	Connecticut	New Haven	76.4	79.3	0.14	0.05	0.14	0.57	0.10	0.40	0.08	0.29	1.15	0.72
390610040	Ohio	Hamilton	75.8	77.1	0.67	0.10	0.52	12.26	0.27	0.12	0.14	1.58	0.11	0.88
360810124	New York	Queens	75.6	77.5	0.06	0.05	0.11	0.35	0.05	0.44	0.12	0.08	2.15	0.82
482010055	Texas	Harris	75.6	77.2	1.30	0.64	0.57	0.18	1.50	0.17	0.16	0.44	0.07	0.06
211850004	Kentucky	Oldham	75.5	79.2	0.43	0.05	0.26	23.48	0.20	0.10	0.08	1.29	0.03	0.35
361030009	New York	Suffolk	75.5	76.7	0.16	0.05	0.17	0.69	0.08	0.26	0.08	0.35	1.30	0.82
421010024	Pennsylvania	Philadelphia	75.4	78.8	0.63	0.17	0.63	2.53	0.20	0.50	0.20	1.08	2.60	3.05
420031008	Pennsylvania	Allegheny	75.3	76.5	0.17	0.07	0.17	1.75	0.08	0.08	0.06	0.65	0.17	2.60
261630019	Michigan	Wayne	75.0	77.2	0.14	0.05	0.12	1.13	0.14	0.38	0.09	0.43	0.29	0.37
360850067	New York	Richmond	75.0	76.6	0.29	0.10	0.33	0.99	0.12	0.50	0.14	0.44	2.11	1.73
340150002	New Jersey	Gloucester	74.9	77.2	0.36	0.14	0.34	1.26	0.13	0.34	0.07	0.40	3.32	2.43
340071001	New Jersey	Camden	74.4	78.3	0.33	0.07	0.16	0.95	0.27	0.08	0.05	0.27	0.33	1.13
340290006	New Jersey	Ocean	74.3	77.1	0.24	0.06	0.19	0.96	0.14	0.36	0.10	0.45	0.87	1.12
340230011	New Jersey	Middlesex	74.0	77.3	0.29	0.10	0.33	1.15	0.11	0.53	0.13	0.50	2.14	2.03
110010043	District of Columbia	District of Columbia	73.6	76.6	0.27	0.07	0.13	1.09	0.10	1.26	0.18	0.29	12.84	2.49
510590030	Virginia	Fairfax	73.5	76.9	0.36	0.09	0.14	1.31	0.10	1.09	0.16	0.30	17.82	2.56
340250005	New Jersey	Monmouth	73.2	76.0	0.17	0.04	0.16	0.67	0.09	0.35	0.08	0.31	1.32	0.96
510130020	Virginia	Arlington	73.1	76.9	0.41	0.10	0.18	1.37	0.15	1.19	0.20	0.36	14.91	2.55
90110124	Connecticut	New London	73.1	76.5	0.10	0.04	0.11	0.41	0.07	0.45	0.09	0.20	1.40	0.56

Nonattainment | Maintenance | Significant impact | Self impact

SEMAP CMAQ BRUTE FORCE SENSITIVITIES

Monitor ID	State	County	2017 Projected Average Design Value	2017 Projected Maximum Design Value	AL	FL	GA	KY	MS	NC	SC	TN	VA	WV
90013007	Connecticut	Fairfield	79.2	81.5	0.07	0.01	0.09	0.53	0.05	0.22	0.05	0.12	1.11	0.59
211850004	Kentucky	Oldham	78.8	81.2	0.16	0.02	0.03	20.97	0.06	0.06	0.04	0.74	0.02	0.09
240251001	Maryland	Harford	78.3	80.9	0.28	0.08	0.27	0.93	0.03	0.09	0.05	0.21	5.06	1.81
361030002	New York	Suffolk	77.8	77.8	0.10	0.02	0.11	0.27	0.03	0.17	0.04	0.16	0.84	0.47
420031008	Pennsylvania	Allegheny	77.3	81.7	0.03	0.02	0.03	0.87	0.02	0.02	0.02	0.27	0.02	0.98
90019003	Connecticut	Fairfield	75.1	77.9	0.07	0.01	0.09	0.51	0.03	0.24	0.05	0.15	1.20	0.60
340071001	New Jersey	Camden	74.3	76.5	0.07	0.03	0.05	0.33	0.07	0.02	0.02	0.05	0.08	0.76
390610006	Ohio	Hamilton	74.1	78.0	0.64	0.05	0.73	8.62	0.20	0.10	0.08	0.85	0.08	0.89
420030008	Pennsylvania	Allegheny	73.9	76.9	0.01	0.01	0.00	0.12	0.04	-0.01	0.00	0.06	0.00	0.86
421010024	Pennsylvania	Philadelphia	73.9	76.1	0.40	0.07	0.36	1.07	0.06	0.08	0.07	0.38	1.09	1.98

Nonattainment

Maintenance

Significant impact

Self impact

COMPUTER RESOURCES

HARDWARE OPTIONS

System	CPUs	Type	RAM	Storage	Cost
Leased Server	72	1 TB	12 TB (RAID5)	24 TB	$3,379/month + $17,500/month
Standalone Workstation	36	1 TB	22 TB (RAID6)	40 TB	$40,000 (upfront) + $8,300 (upfront)
Cloud Computing	64	1 TB	2 TB	40 TB	$5,000/month + $1,600/month

WHY SO MUCH COMPUTER POWER?

- **Need to solve the Atmospheric Diffusion Equation for each species in each grid cell for each time step**
- **(269 * 242 horizontal grid cells) x (25 vertical layers) x (100 species) x (4 time step/hour) x (24 hours/day) x (365 days/year)**
- **IN AN ANNUAL SIMULATION, NEED TO SOLVE OVER 5,700,000,000,000 PARTIAL DIFFERENTIAL EQUATIONS!!!!**

$$\frac{\partial c_i}{\partial t} + \nabla \cdot (\mathbf{u}\, c_i) = \nabla \cdot (\mathbf{K}\, \nabla c_i) + R_i + S_i$$

PERSONNEL

DMU ORGANIZATIONAL STRUCTURE

Di Tian, Ph.D.
Data & Modeling Unit

<u>Dispersion Modeling Team</u>
Yan Huang, Ph.D.
Henian Zhang, Ph.D.
Yunhee Kim, Ph.D.

<u>PGM Modeling Team</u>
Byeong Kim, Ph.D.
Tao Zeng, Ph.D.
Vacant, Ph.D.

MODELING STAFF QUALIFICATIONS

- Advanced degree in chemical engineering, mechanical engineering, environmental engineering, atmospheric sciences, or meteorology
- Experience running numerical models
- Knowledge of EPA rules and guidance related to modeling
- Background in scientific computer programming (FORTRAN), database management (MYSQL and ACCESS), Geographic Information System (GIS), and experience with Linux or Unix.

MODELING STAFF RESPONSIBILITIES

- Run the Model (this is the EASY part)
- Develop Modeling Objectives
- Design Modeling Approach
- Create Model Inputs
- Post-Process Model Outputs
- Analyze and Interpret Results
- Identify Errors and Debug Code
- Document Results

ON-GOING STAFF DEVELOPMENT

- **Formal Training**
  - WRF, SMOKE, CMAQ, CAMx, BenMAP, CMAS MPE
- **Attend National Conferences**
  - CMAS, AWMA, EPA Workshops, others…
- **Participate on National Workgroups Calls**
  - EPA, AAPCA, NACAA
- **Read Journal Articles**
- **Read EPA Guidance Documents and Memos**
- **Review EPA Rulemaking TSDs**
  - Understand EPA modeling approaches
  - Replicate EPA modeling
- **Participate in Regional Modeling Projects**
  - Conference Calls, Review Technical Reports

IT SUPPORT

SYSTEM ADMINISTRATION

- **Hardware**
  - Upgrading/repairing hardware components
  - Configuring/connecting disks
- **Operating System**
  - User/Group Management (e.g. File Permission)
  - Configuring system software
  - Installing patches and upgrading operating system
  - Network/Security Configuration (e.g., SSH and Firewall)
  - Managing licenses for modeling related software (e.g., FORTRAN compiler)
- **Modeling Applications**
  - Compiling modeling related software such as IOAPI, CAMx, and CMAQ
  - Backup and archiving
  - Trouble-shooting

IT SUPPORT OPTIONS

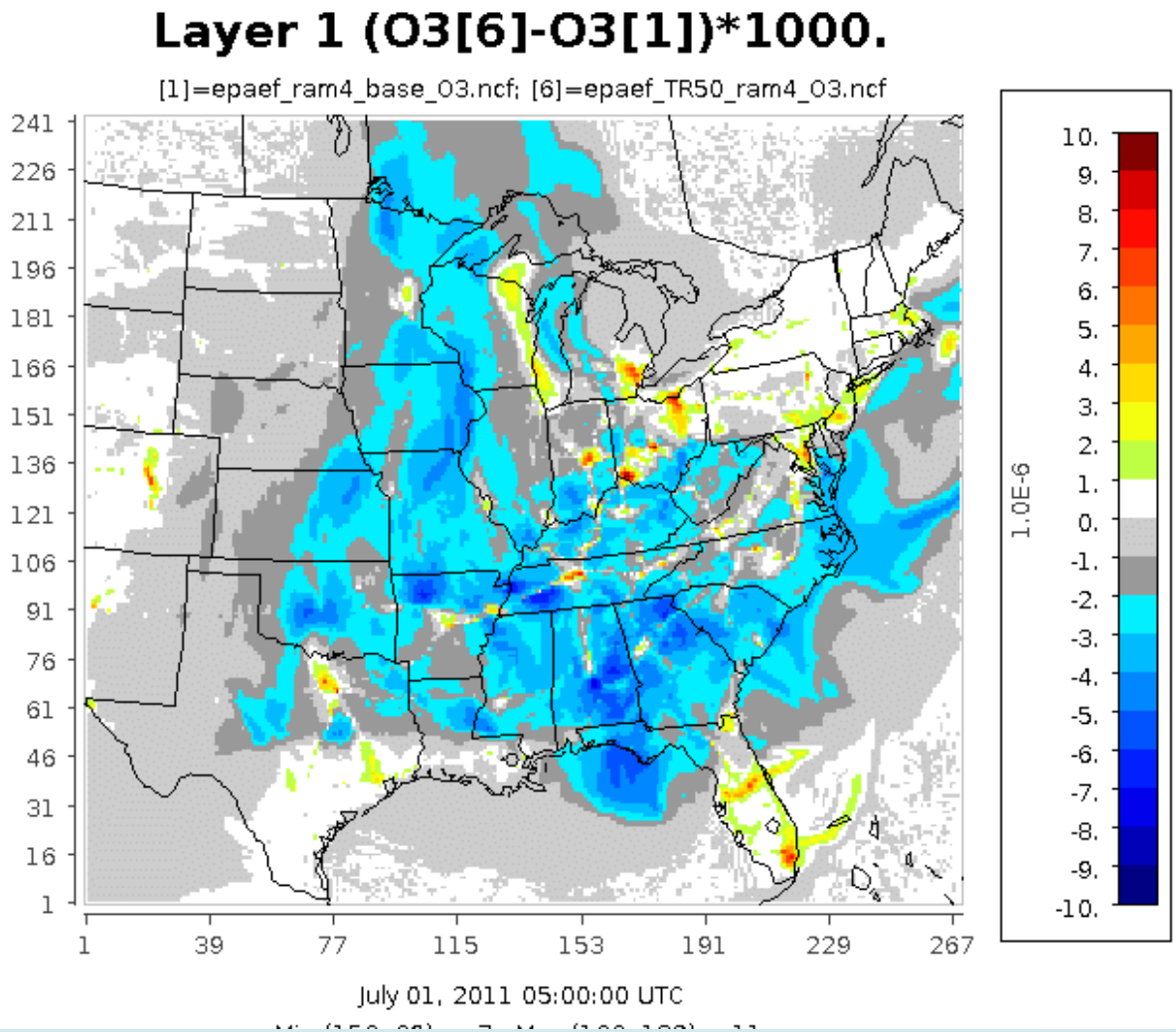
System	Hardware Repairs	Hardware Maintenance	Operating System	Modeling Applications
Leased Server	Contractor	Contractor	Contractor	EPD Staff
Standalone Workstation	Contract ($1000/3 years)	EPD Staff	EPD Staff	EPD Staff
Cloud Computing	Behind the scenes (N/A)	Vendor	EPD Staff	EPD Staff

EXAMPLE APPLICATIONS

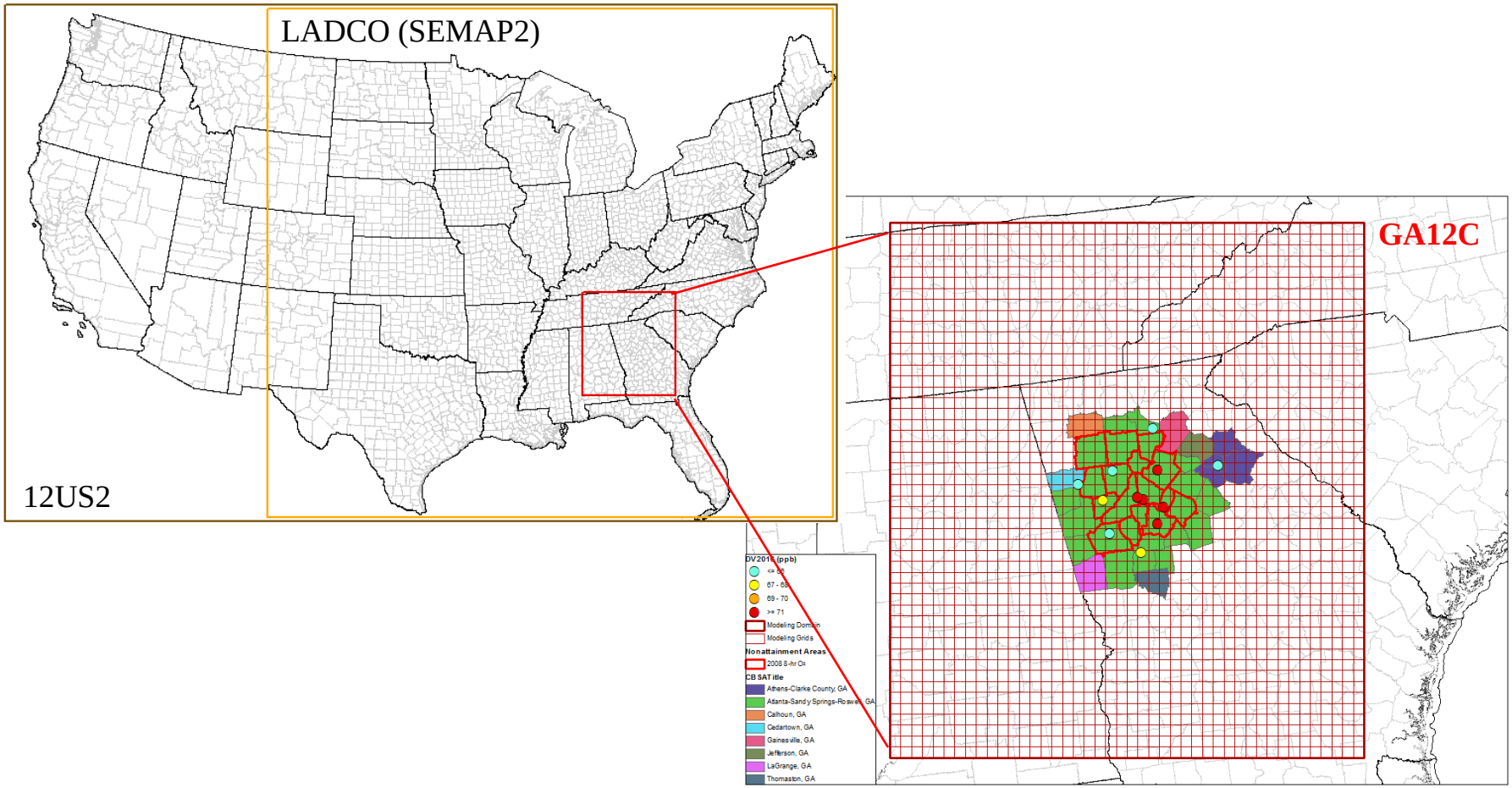
EXAMPLE APPLICATIONS

- **Ozone projection modeling for attainment SIPs**
  - 2008/2015 ozone standards
- **Ozone transport modeling for infrastructure SIPs**
  - 2008/2015 ozone standards
- **Visibility modeling for Regional Haze SIPs**
  - Reasonable Progress Goals (RPGs)
- **Designation recommendations**
  - 2015 ozone standard
- **PSD Permit Modeling**
  - Secondary $PM_{2.5}$ and ozone impacts (Appendix W)
- **Special Projects**

50% REDUCTION ON-ROAD NOx



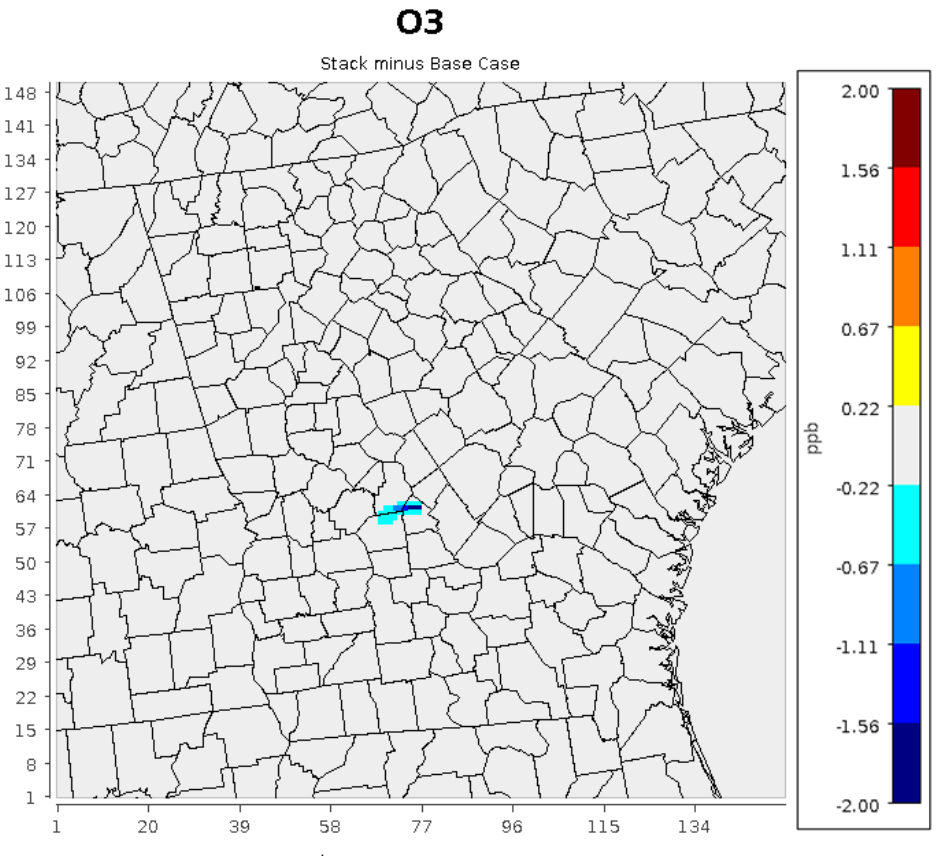
2015 OZONE RECOMMENDATIONS

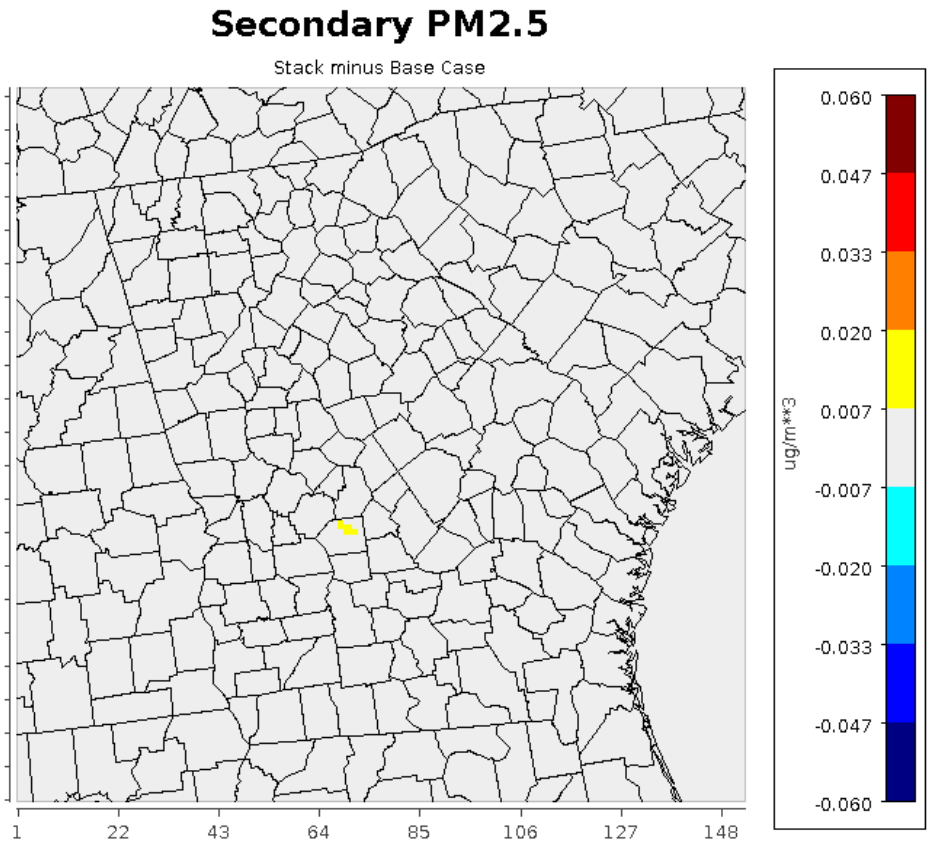


COUNTY LEVEL CONTRIBUTIONS

Monitor	Confederate Ave. (13-121-0055)	Conyers (13-247-0001)	McDonough (13-151-0002)	Gwinnett Tech (13-135-0002)	South DeKalb (13-089-0002)
Barrow	0.12	0.06	0.10	0.23	0.10
Bartow	**1.17**	0.77	0.97	**1.45**	0.96
Butts	0.04	0.07	0.14	0.02	0.04
Carroll	0.24	0.33	0.15	0.09	0.26
Cherokee	0.40	0.30	0.36	0.64	0.33
Clarke	0.08	0.03	0.10	0.09	0.08
Clayton	**3.54**	**4.22**	**3.85**	0.68	**3.26**
Cobb	**2.69**	**1.50**	**1.72**	**2.49**	**2.05**
Coweta	0.24	0.38	0.29	0.14	0.23
Dawson	0.03	0.03	0.03	0.04	0.03
DeKalb	**3.04**	**3.07**	**3.17**	**2.33**	**5.56**
Douglas	0.68	0.41	0.33	0.16	0.55
Fayette	0.21	0.31	0.40	0.07	0.18
Forsyth	0.29	0.26	0.24	0.78	0.24
Fulton	**8.74**	**4.12**	**4.07**	**3.92**	**5.98**
Gordon	0.15	0.11	0.14	0.07	0.13
Gwinnett	**1.71**	**1.93**	**1.60**	**8.25**	**1.58**
Hall	0.26	0.18	0.16	0.61	0.19
Haralson	0.07	0.10	0.03	0.04	0.09
Heard	0.14	0.26	0.16	0.09	0.15
Henry	0.55	**2.65**	**4.08**	0.26	0.88
Jackson	0.16	0.07	0.12	0.29	0.13
Jasper	0.01	0.01	0.03	0.01	0.01
Lamar	0.01	0.02	0.03	0.01	0.01
Madison	0.07	0.03	0.07	0.11	0.07
Meriwether	0.02	0.03	0.03	0.02	0.03
Morgan	0.06	0.02	0.08	0.03	0.06
Newton	0.17	0.29	0.34	0.06	0.21
Oconee	0.04	0.01	0.05	0.04	0.04
Oglethorpe	0.01	0.00	0.01	0.01	0.01
Paulding	0.35	0.20	0.22	0.20	0.29
Pickens	0.05	0.05	0.05	0.03	0.05
Pike	0.01	0.01	0.02	0.01	0.01
Polk	0.09	0.06	0.05	0.07	0.08
Rockdale	0.23	0.95	0.41	0.09	0.31
Spalding	0.04	0.10	0.15	0.03	0.05
Troup	0.03	0.04	0.04	0.03	0.04
Upson	0.01	0.01	0.01	0.01	0.01
Walton	0.16	0.09	0.20	0.14	0.17

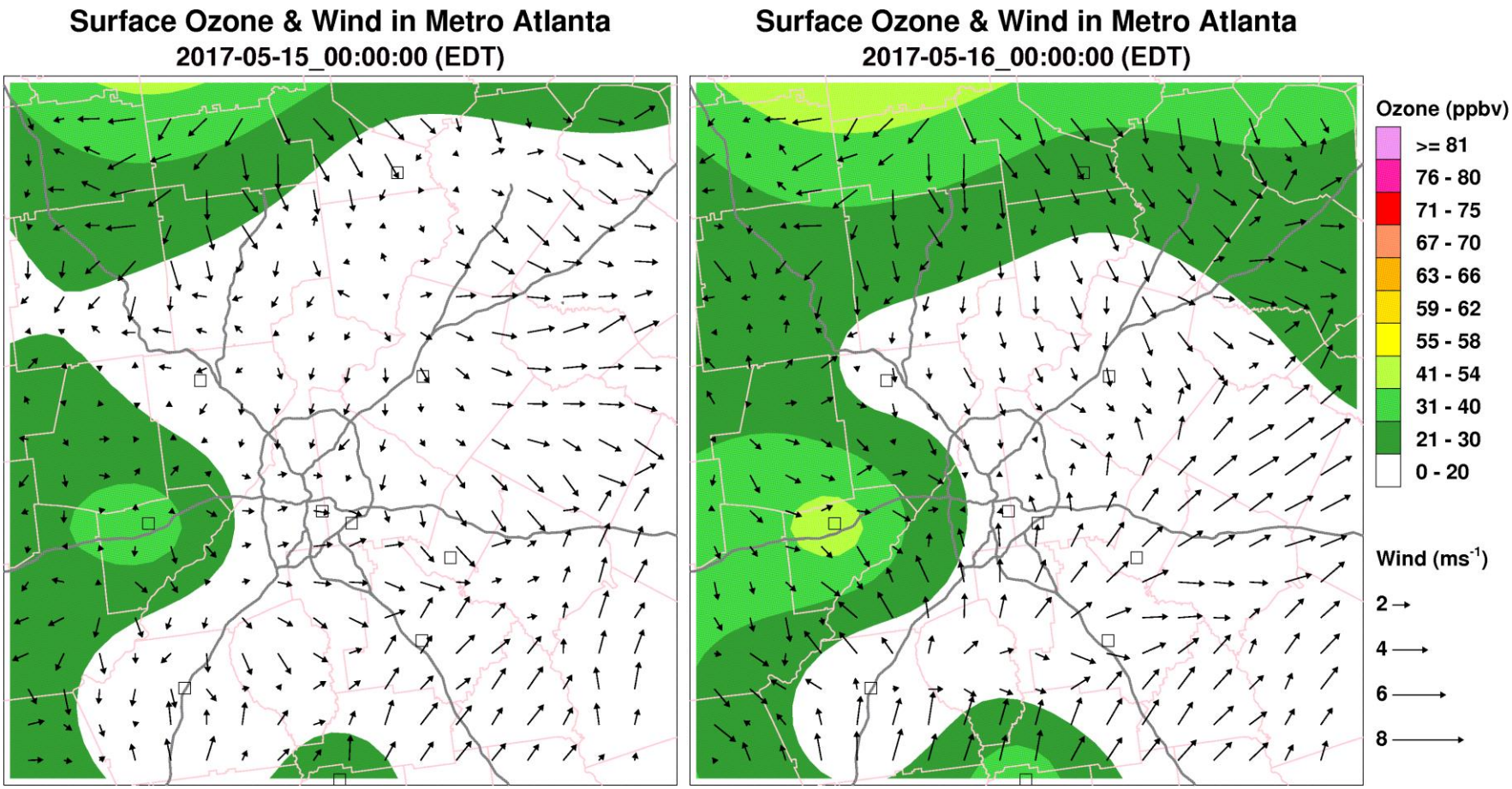
SINGLE SOURCE PSD PERMITTING





GOOGLE TRAFFIC MAP ON JULY 26

OZONE ANIMATIONS



CONTACT INFORMATION

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