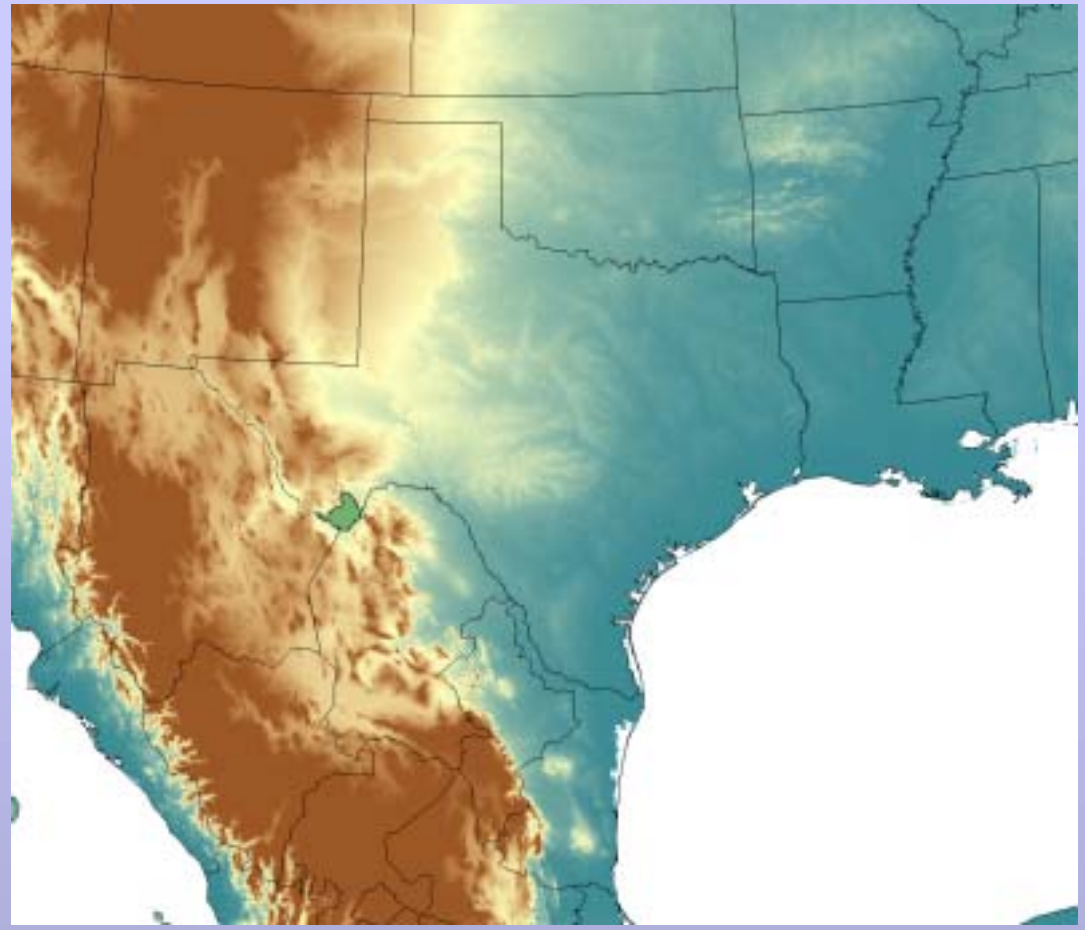
The Emission Inventories and SMOKE modeling efforts used to support the BRAVO study



Hampden Kuhns
Desert Research Institute
2215 Raggio Pky, Reno, NV 89512
Jeffrey M. Vukovich
MCNC-Environmental Modeling Center
3021 Cornwallis Road, Research Triangle Park, NC 27709

BRAVO Study

Acknowledgements:

-EPA, NPS, TNRCC, EPRI, and TXU

Study Goals:

- Understand the importance of long-range pollution transport to haze conditions in Big Bend National Park, Texas
- Determine the relative influence of emissions sources in the region on Big Bend haze

Inventory Domain

Inventory Data Sources

	United States	Mexico	Off Shore
Area	• NEI database for 14 BRAVO States. • Replace TX sources for Construction and Oil and Gas using NONROAD model with TNRCC Activity	• ERG Emissions Factors from TJ, CJ, and Mexicalli supplemented with Monterrey emissions • Extrapolate emissions across non inventoried areas based on activity from MX Census	• N/A
Mobile	• NEI county level database for 14 BRAVO States. • Replace TX onraod mobile with 1996 base year emissions from TTI	• ERG Emissions Factors from TJ, CJ, and Mexicalli supplemented with Monterrey emissions • Extrapolate emissions across non inventoried areas based on activity from MX Census	• N/A
Point	• CEM database for point sources in 14 BRAVO states • NEI Point sources from 14 BRAVO states	• Acosta y Associados-42 Power plants based on fuel use and type. • ERG-Cabon I/II and Nacazari • Watson/Profepa-20 SO2 sources • CENAPRED-Popocatepetl Volcano • INEGI-Mexico City and Tula	• MMS MOAD3 database
Biogenic	• Calculated by MCNC in SMOKE	• Calculated by MCNC in SMOKE	• N/A

U.S. Emissions Inventory

- 1999 base year Nation Emissions Inventory (NEI) Version 100
  - Base on 1996 NET EI
  - Area and mobile sources resolved at at County level
  - Point sources resolved at process level
  - Species: CO, NH_3, NO_x, PM_{10}, $PM_{2.5}$, SO_2, VOC
  - Annual and Ozone Season Day Emissions
- Continuous Emissions Monitoring
  - Hourly emissions from power plants with CEM data

Adjustments to US NEI

- Replaced construction and oil and gas sources for TX with TNRCC activity data.
  - 25% to 50% reduction in emission of all species
  - Sources account for < 2% of SO_2 in state
- Replace commercial marine with emissions from Starcrest 2000 EI.
  - Affects Harris, Galveston, Chambers, and Brazoria Counties
  - Reduces NO_X emissions by factor of 10 due to NEI basing emissions on fuel sales. Starcrest EI bases emissions on operation activity in harbor.
- Total ammonia emissions from UTA report were within 5% of NEI emissions.
  - BRAVO EI uses NEI emissions for consistancy with data formatting.
- Mobile sources replaced with 1996 TRNCC data.
  - Increased onroad mobile emissions by 15% to 50% in TX
  - Mobile are major (>20%) sources of CO, No_x, and VOC.

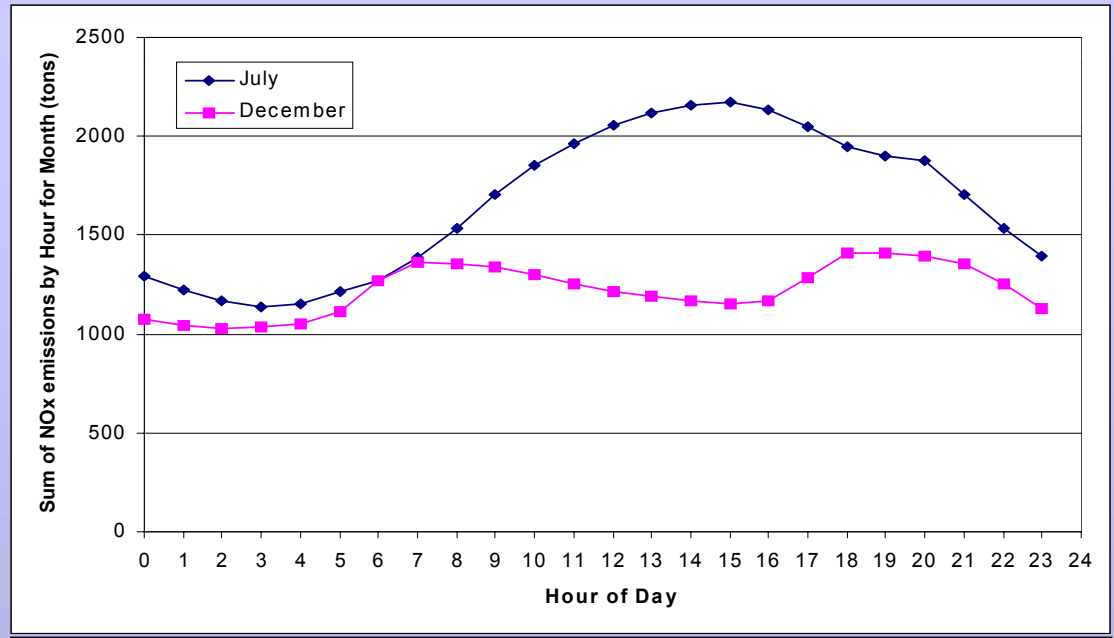
CEM Data

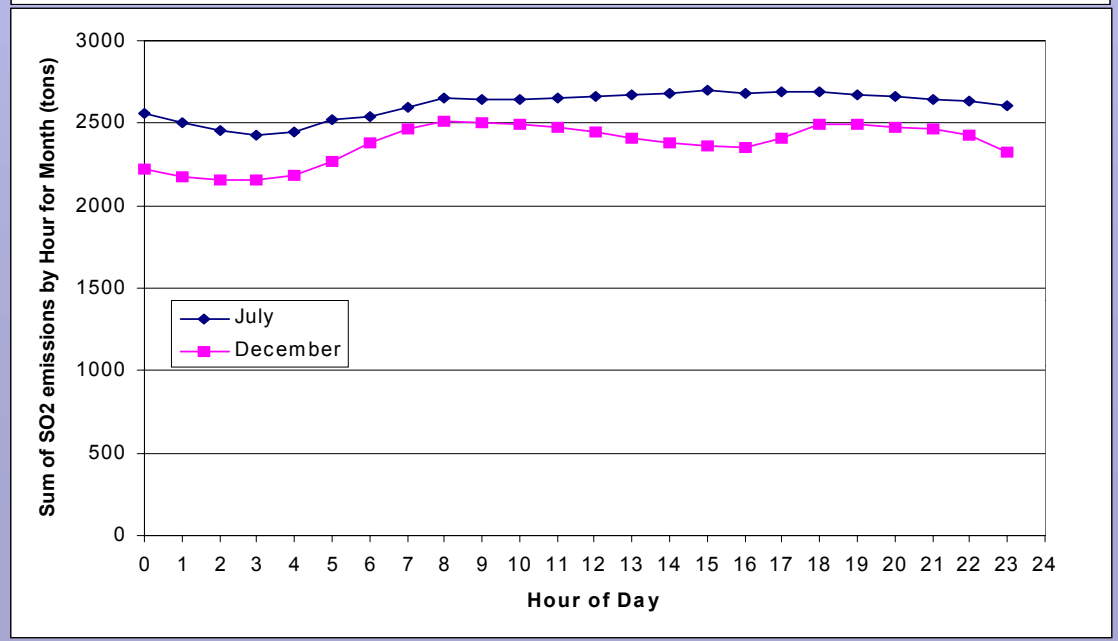
- CEM's record emissions of NO_x, SO_2, and CO_2 from power plant stacks.
- CEM's reconciled with NEI for 477 unique systems in the 14 BRAVO states
- CO, NH_3, PM_{10}, $PM_{2.5}$, and VOC scaled to NO_x emissions based on annual NEI profiles

Diurnal Texas CEM Results

- NO_x emissions peak during hottest time of day in Summer.

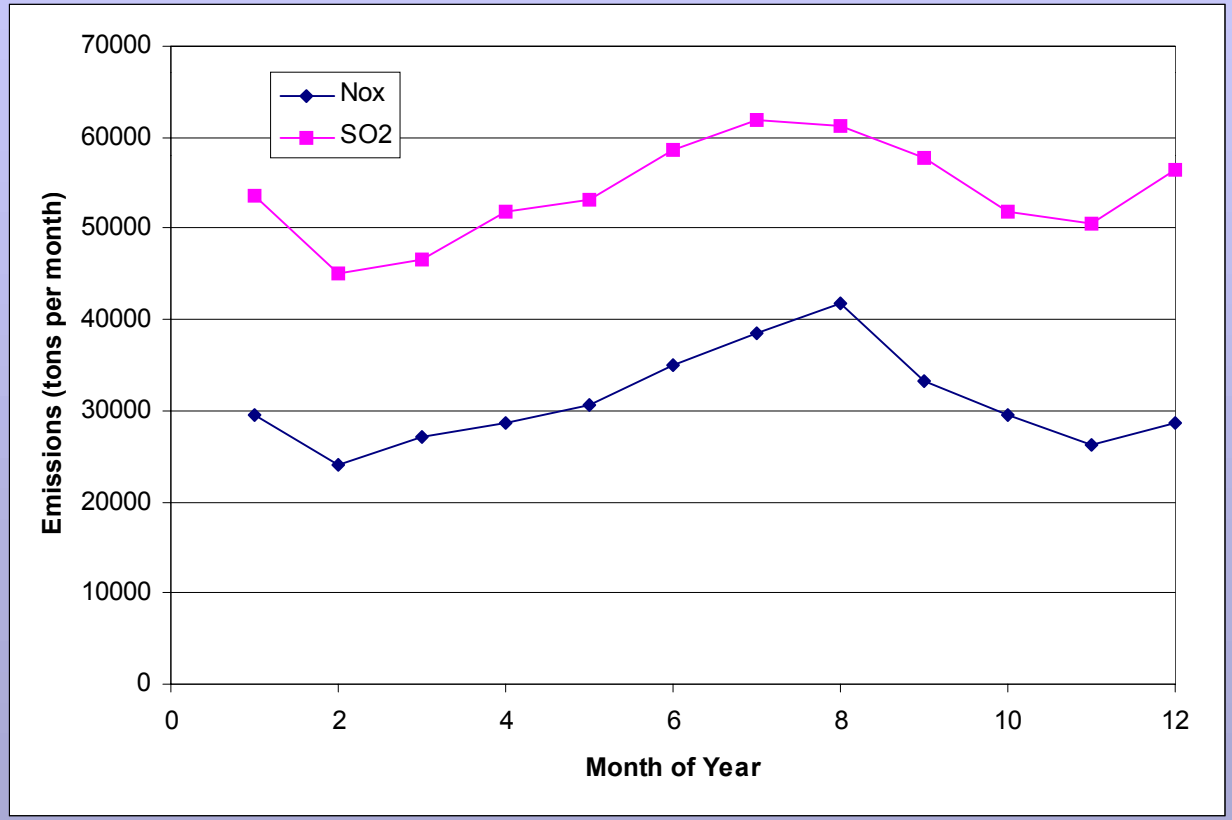
- SO_2 emissions are consistent year round.





Annual CEM Cycle

- July and August are highest SO_2 emissions months.
- NO_x follows similar annual trend to SO_2



Mexican Emissions Inventory

- Area and mobile sources based on Eastern Research Group's WRAP emissions inventory for NW Mexico
  - Emissions factors averaged from inventories in Tijuana, Mexicalli, Ciudad Juarez, and Monterrey
  - Emissions extrapolated over non inventoried "Municipios" using Census data for:
    - Population
    - Households
    - Agricultural Acreage
    - Head of Cattle
    - Registered Vehicles
- Point source emissions were obtained from a variety of sources

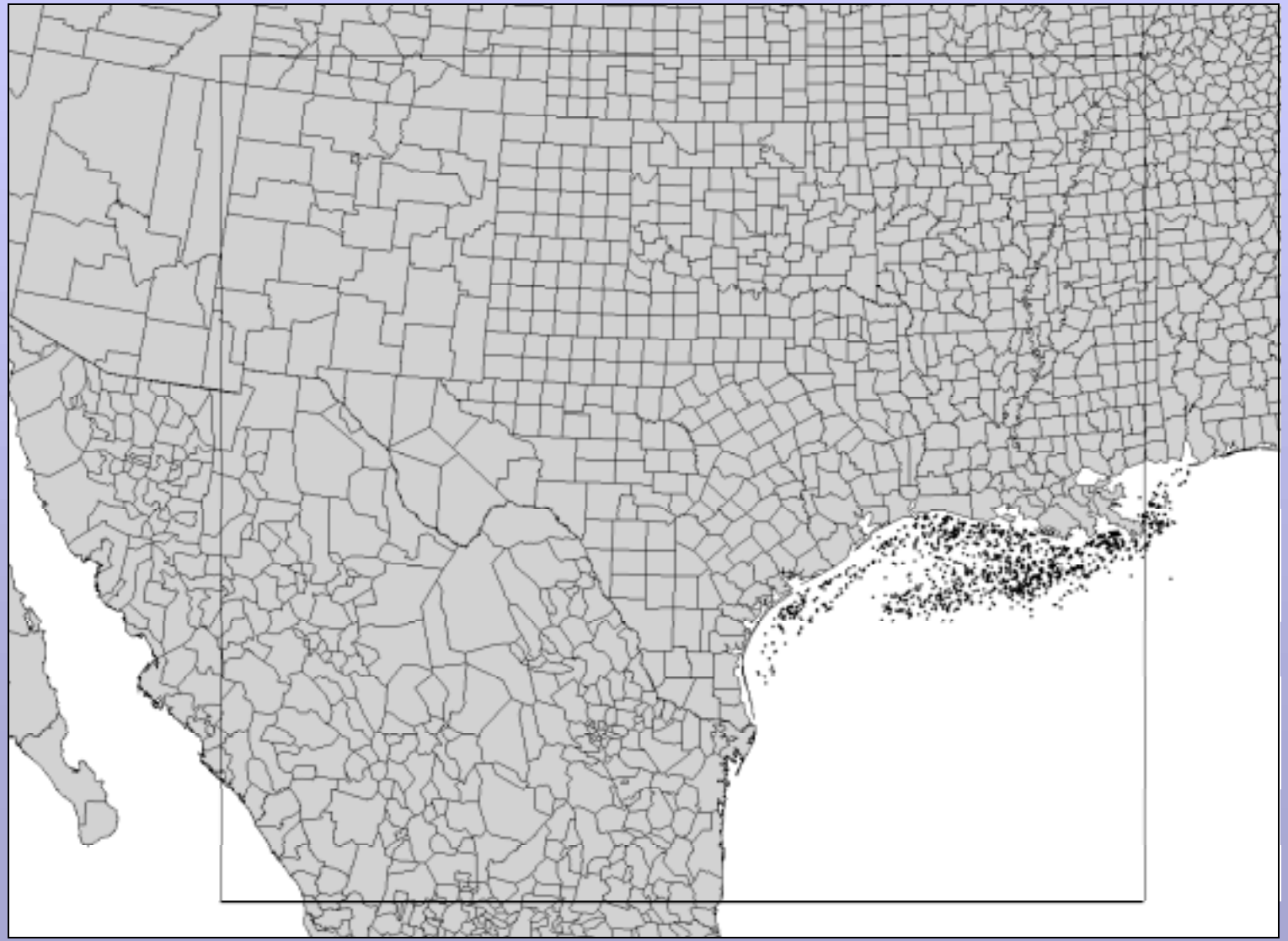
Mexican Point Sources

Point Source	Data Source	SO_2 Emissions (tpy)
Popocatepetl Volcano	CENEPRED	1,400,000
Tula-Vito-Apaxco	INEGI	355,000
42 Power Plants in Northern MX	Acosta y Associados	316,000
Carbon I/II	Yarborough /EPA	155,000
Other Industrial Sources	Watson /PROFEPA	73,000

Offshore: Minerals Management Service Outer Continental Activity Database (MOAD)

- Emissions from platforms
- Major sources
  - Boilers
  - Diesel generators
  - Tanks breathing
  - Gas flaring
- Inventory base year 1992.
- All species emissions are less than 5% Texas total.
- Particle emissions may be grossly underestimated as emissions from flaring were not reported.

Map of Offshore Sources

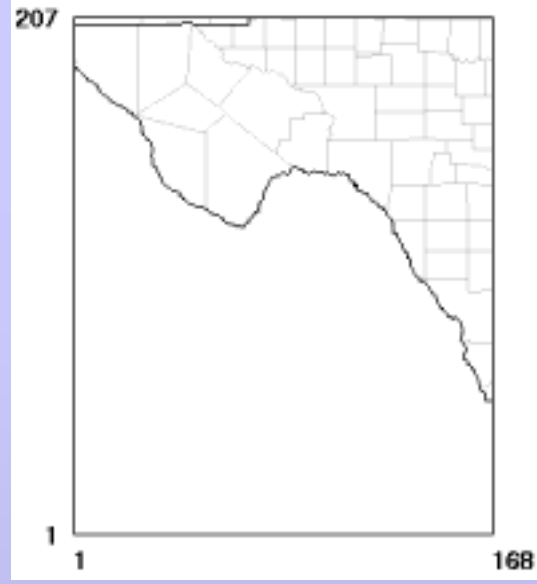


SMOKE Emission Processing

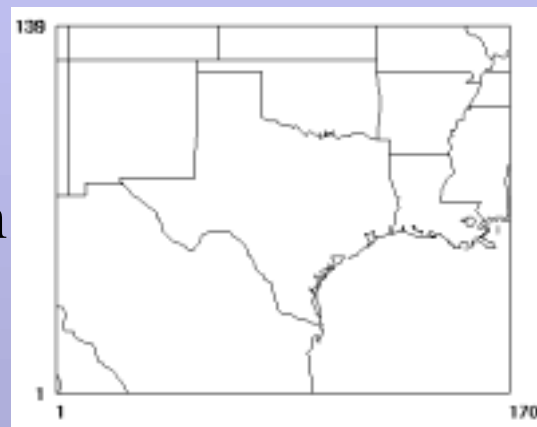
- Temporally, spatially, and chemically apportions EI to run regional air quality models (REMSAD and CMAQ(
- Input area, mobile, and point source emissions
- Calculate biogenic emissions and sea salt emissions with land use and meteorological data input
- Surrogate variables such as population, highways, agriculture, and forests were used spatially allocate emissions

REMSAD Modeling Grids

4 km



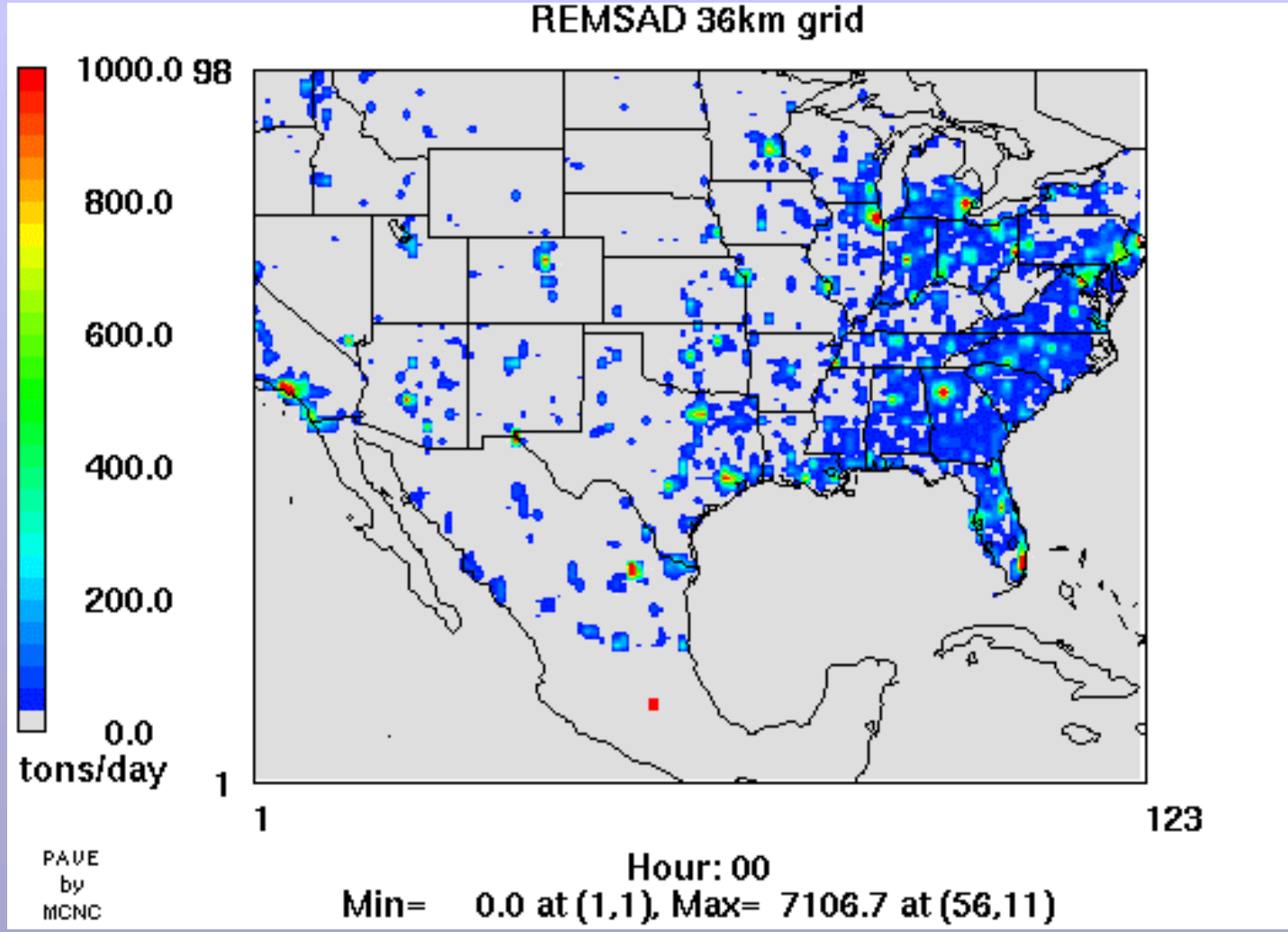
12 km



36 km

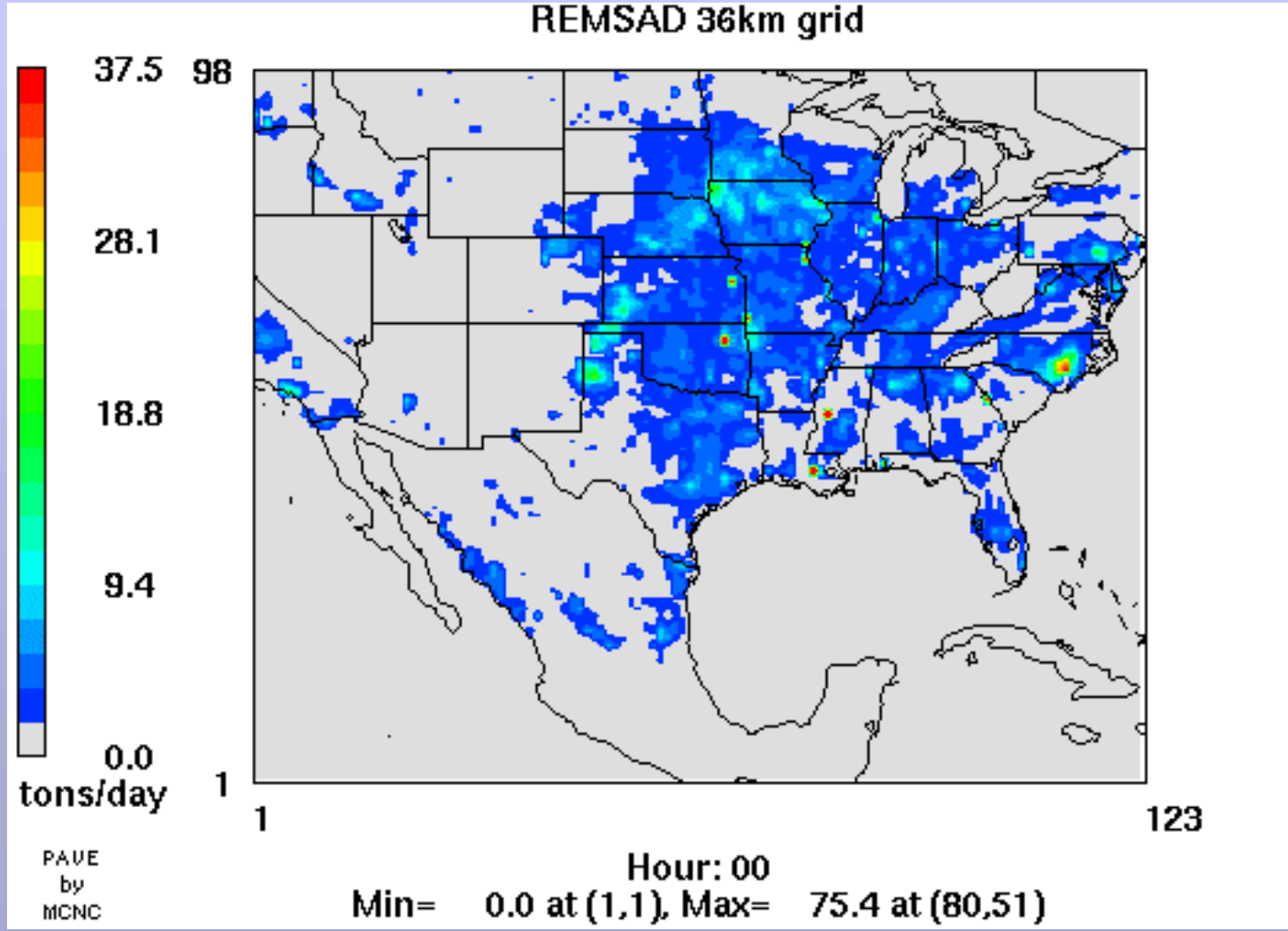
CO Emissions in BRAVO EI

Region	CO
U.S. BRAVO EI States Major Sources	Highway light duty gasoline vehicles (30%) Highway light duty gasoline trucks (12%) 4-Stroke Lawn and garden equipment (9%)
U.S. BRAVO EI States Total	28.8 MT/yr
Mexican BRAVO EI States Major Sources	Highway light duty gasoline vehicles (60%) Highway light duty gasoline trucks (22%) Agricultural field burning (9%)
Mexican BRAVO EI States Total	7.2 MT/yr
Offshore Major Sources	Reciprocating engines natural gas (81%) Turbine engines natural gas (12%) Flaring (3%)
Offshore Total	0.022 MT/yr



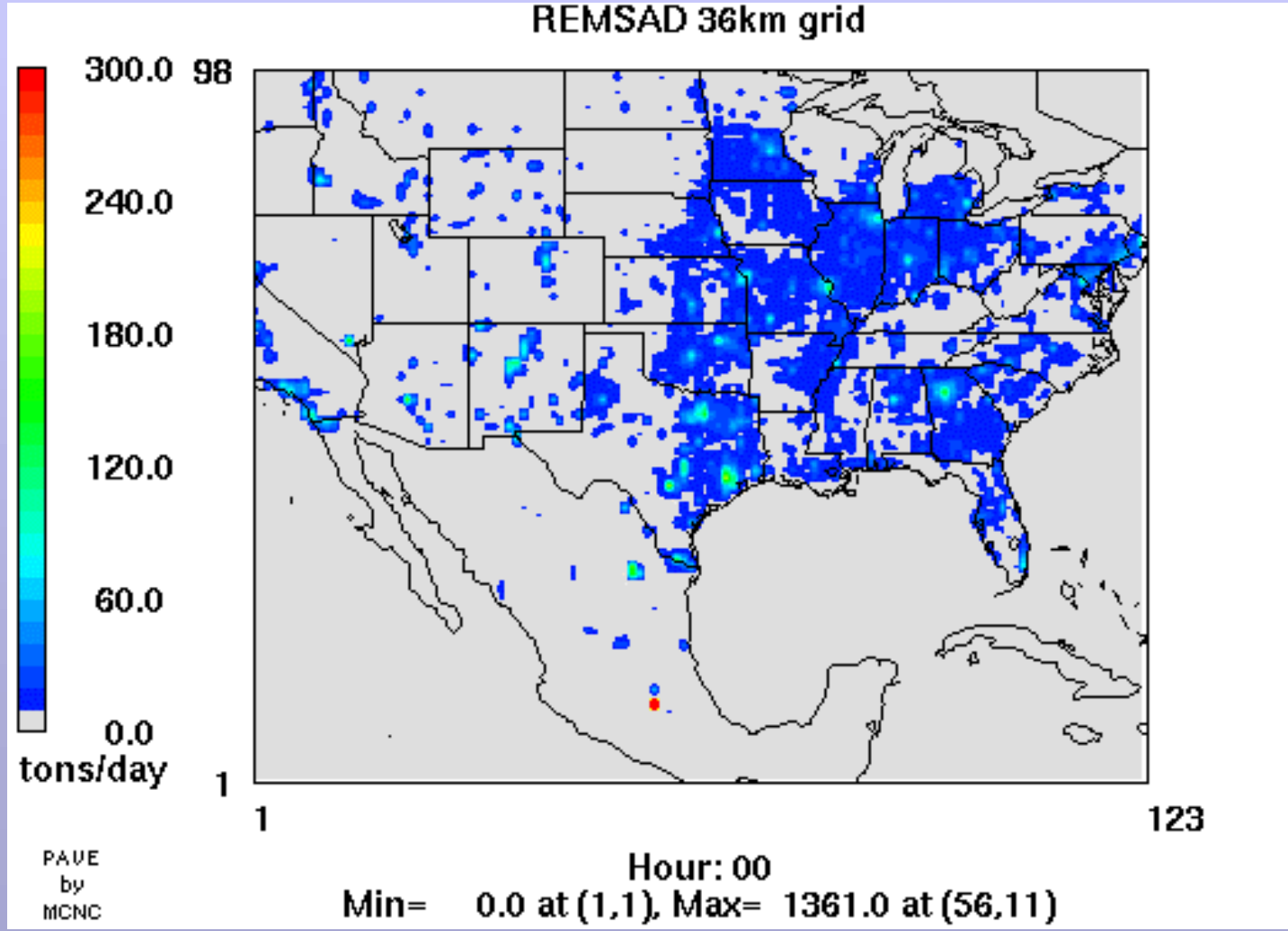
NH_3 Emissions in BRAVO EI

Region	NH_3
U.S. BRAVO EI States Major Sources	Cattle and Calves (58%) Fertilizer Application (15%) Hogs and Pigs (8%)
U.S. BRAVO EI States Total	2.1 MT/yr
Mexican BRAVO EI States Major Sources	All livestock (55%) Fertilizer Application (37%) Domestic ammonia (8%)
Mexican BRAVO EI States Total	0.3 MT/yr
Offshore Major Sources	
Offshore Total	0.000 MT/yr



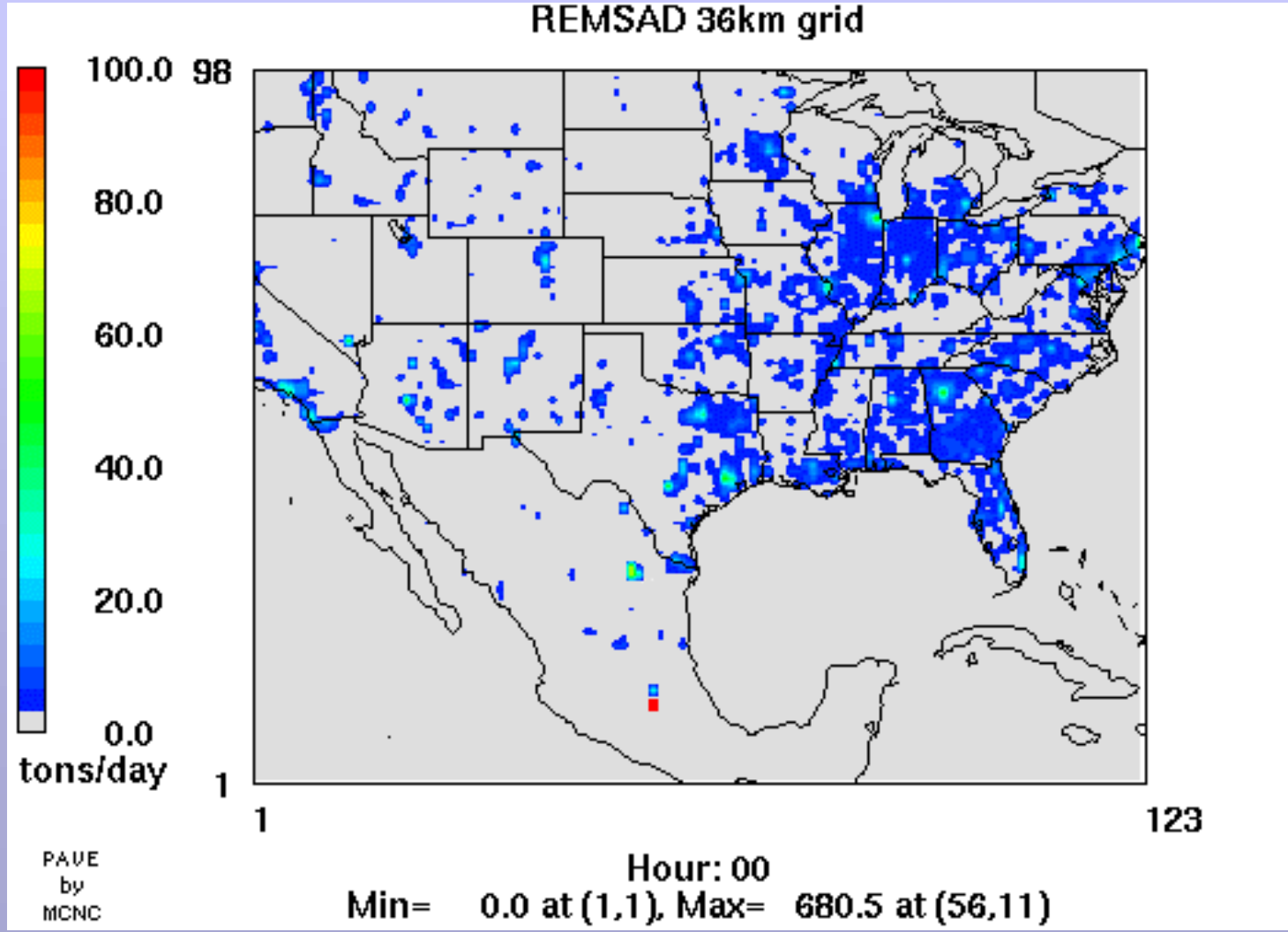
PM_{10} Emissions in BRAVO EI

Region	PM_{10}
U.S. BRAVO EI States Major Sources	Unpaved roads (47%) Agriculture crop tilling (19%) All paved roads (8%)
U.S. BRAVO EI States Total	9.9 MT/yr
Mexican BRAVO EI States Major Sources	Unpaved roads (58%) Agriculture crops field burning (10%) All paved roads (7%)
Mexican BRAVO EI States Total	0.9 MT/yr
Offshore Major Sources	Reciprocating engines natural gas (58%) Turbine engines natural gas (30%) Reciprocating engines diesel (9%)
Offshore Total	0.002 MT/yr



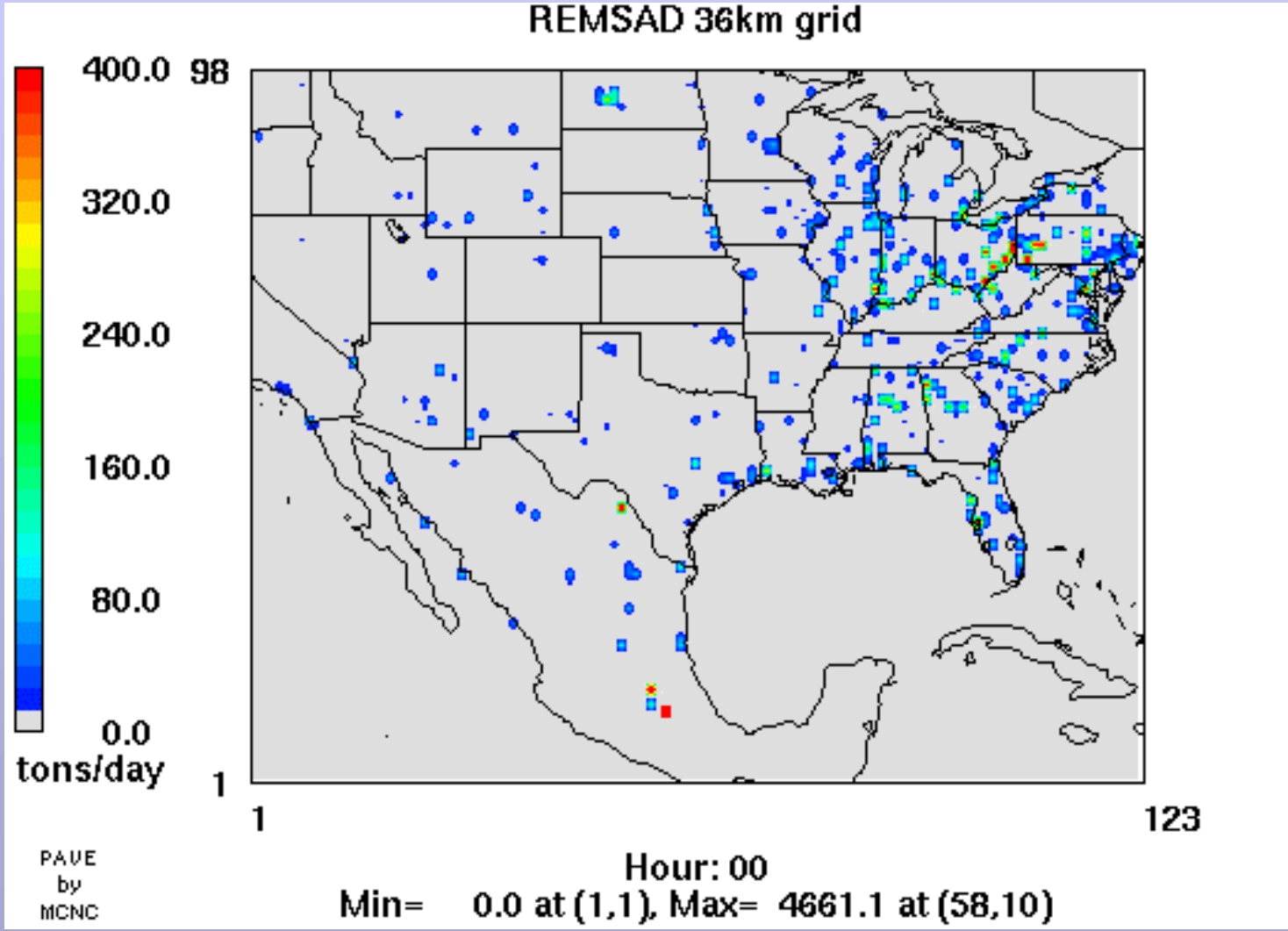
$PM_{2.5}$ Emissions in BRAVO EI

Region	$PM_{2.5}$
U.S. BRAVO EI States Major Sources	Unpaved roads (29%) Agriculture crop tilling (15%) All paved roads (8%)
U.S. BRAVO EI States Total	2.4 MT/yr
Mexican BRAVO EI States Major Sources	Unpaved roads (34%) Agriculture crops field burning (27%) All paved roads (9%)
Mexican BRAVO EI States Total	0.3 MT/yr
Offshore Major Sources	Reciprocating engines natural gas (58%) Turbine engines natural gas (30%) Reciprocating engines diesel (9%)
Offshore Total	0.002 MT/yr



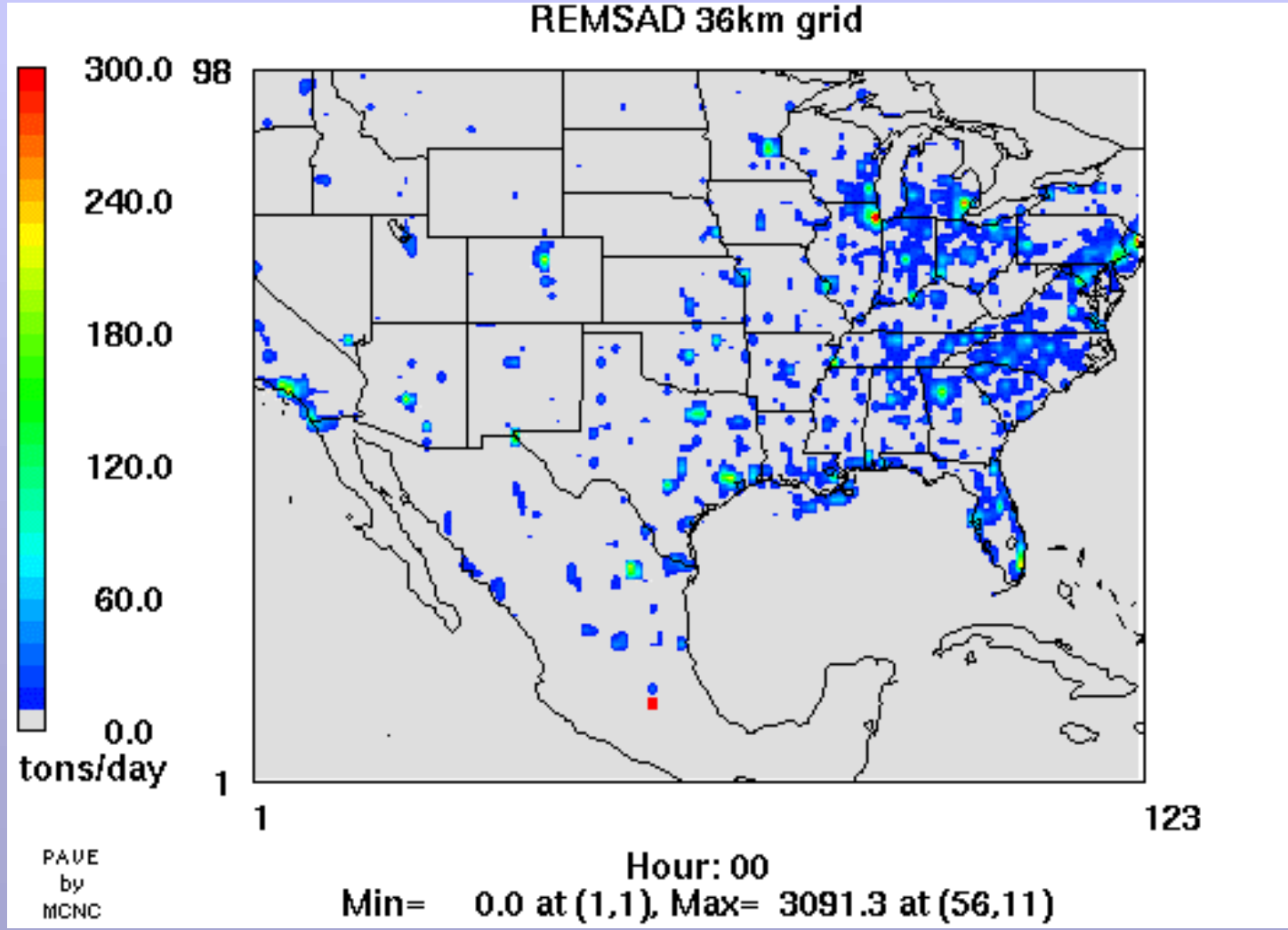
SO_2 Emissions in BRAVO EI

Region	SO_2
U.S. BRAVO EI States Major Sources	Electric Generation Bituminous/Subbituminous Coal (53%) Electric Generation Lignite Coal (7%) Industrial Bituminous /Subbituminous Coal (4%)
U.S. BRAVO EI States Total	5.8 MT/yr
Mexican BRAVO EI States Major Sources	Popocatepl Volcano (65%) Electric Generation Residual Oil (12%) Electric Generation Lignite Coal (10%)
Mexican BRAVO EI States Total	2.6 MT/yr
Offshore Major Sources	Reciprocating diesel engine (79%) Large bore diesel engine (10%) Reciprocating engines natural gas (5%)
Offshore Total	0.000 MT/yr



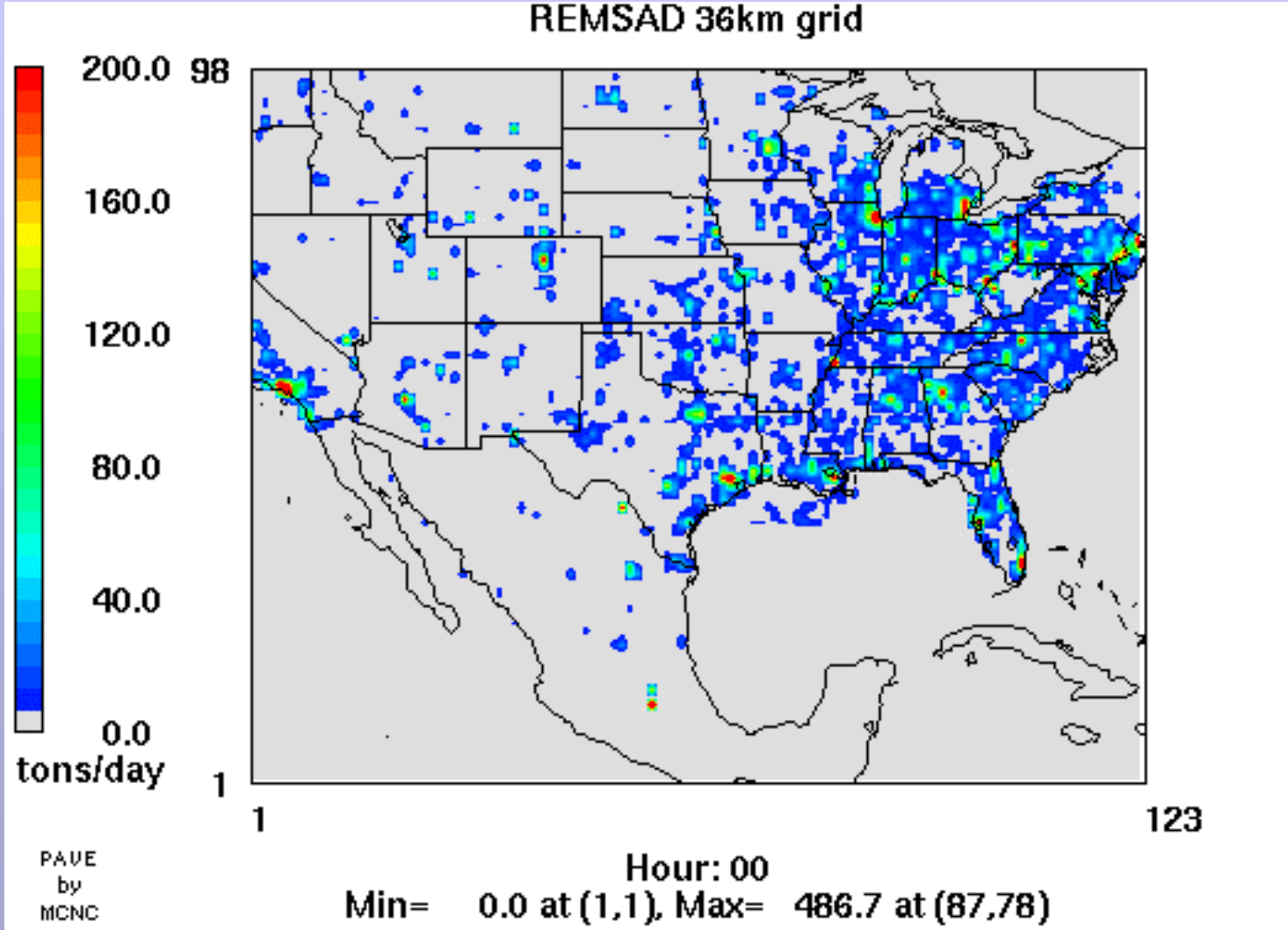
VOC Emissions in BRAVO EI

Region	VOC
U.S. BRAVO EI States Major Sources	Highway light duty gasoline vehicles (17%) Highway light duty gasoline trucks (7%) Gasoline service stations (5%)
U.S. BRAVO EI States Total	5.8 MT/yr
Mexican BRAVO EI States Major Sources	Highway light duty gasoline vehicles (35%) Highway light duty gasoline trucks (13%) Petroleum Storage and Transport (10%)
Mexican BRAVO EI States Total	1.4 MT/yr
Offshore Major Sources	Flaring (82%) Reciprocating engines natural gas (13%) Crude oil tank breathing (4%)
Offshore Total	0.278 MT/yr

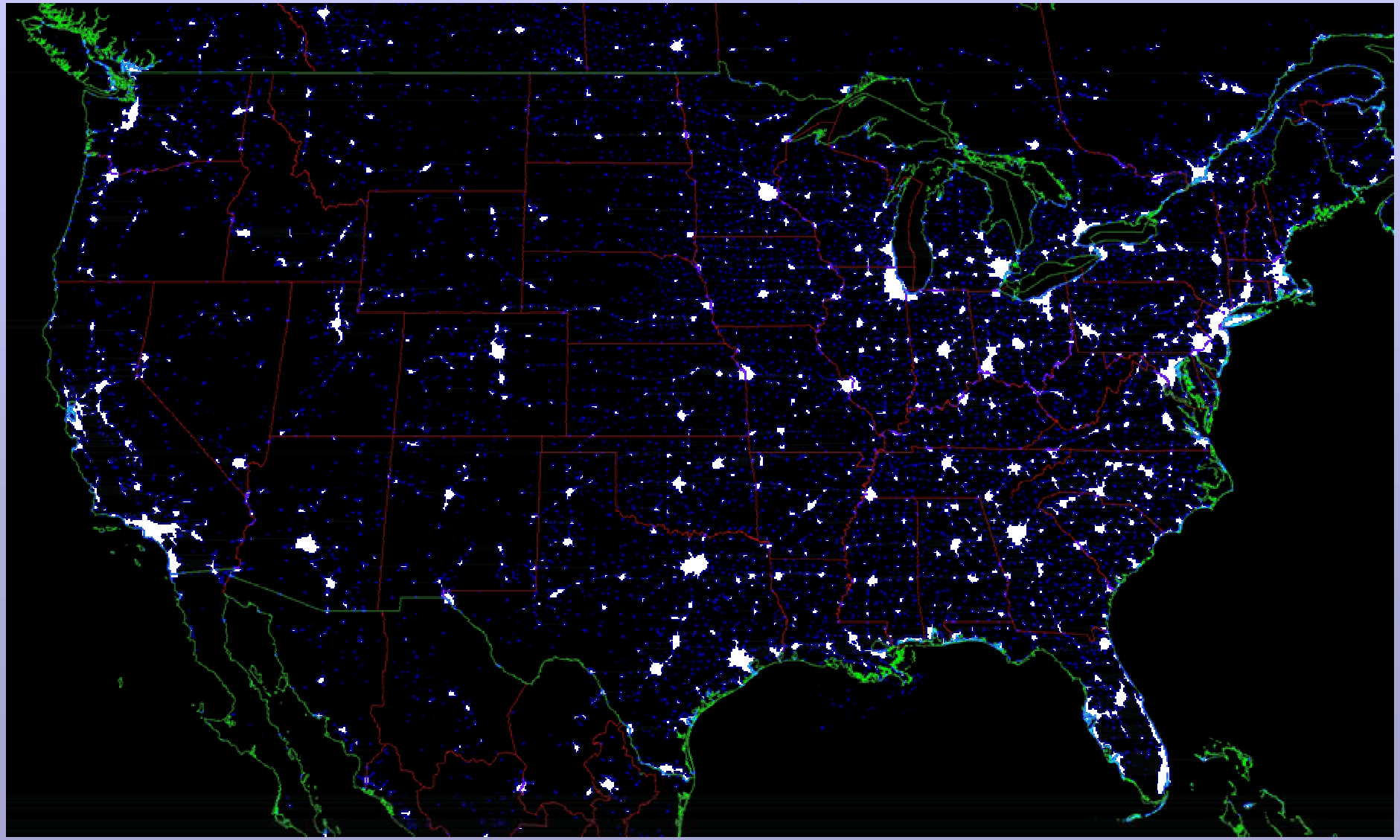


NO_x Emissions in BRAVO EI

Region	NO_x
U.S. BRAVO EI States Major Sources	Electric Generation Bituminous/Subbituminous Coal (18%) Highway heavy duty diesel vehicles (12%) Highway light duty gasoline vehicles (10%)
U.S. BRAVO EI States Total	9.4 MT/yr
Mexican BRAVO EI States Major Sources	Highway light duty gasoline vehicles (34%) Electric Generation Lignite Coal (15%) Highway heavy duty diesel vehicles (12%)
Mexican BRAVO EI States Total	0.6 MT/yr
Offshore Major Sources	Reciprocating engines natural gas (87%) Turbine engines natural gas (6%) Natural gas Boilers (4%)
Offshore Total	0.093 MT/yr



BRAVO Study Domain at Night



Conclusions

- BRAVO EI compiled from existing EI's and newly synthesized data for South Central U.S. and Northern Mexico for base year 1999.
- Similar sources categories dominate species emissions in both countries despite differences in methodologies
- Largest SO_2 sources near Big Bend are Electric Utilities in Mexico and in Eastern Texas
- Popocatepetl Volcano south of Mexico City dominates Mexican SO_2 emissions Inventory.
- Inventory was processed using SMOKE to generate a modeling EI.

Recommendations

- Need vegetative burning emissions (via remote sensing)
- Need improved flaring emissions from offshore activities (currently VOC only)
- Need comprehensive point source database for Mexico