



Emissions Processing and Sensitivity Air Quality Modeling of Category 3 Commercial Marine Vessel Emissions

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Background

- Analysis of Category 3 (C3) CMV Emissions in 2002 NEI (V3.0) vs. Draft Modified-STEEM (Waterway Network Ship Traffic, Energy, and Environmental Model)
- "C3" defined: Cat 3 propulsion engines + auxiliary –not necessarily residual fuel or OGV

NEI C3 Methodology

- Top-down national estimates allocated to specific large ports
 - supplemented/replaced with some state data where provided
 - slightly over-estimates C3 emissions at these ports (not all ports on list)
 - C3 and C2 treated essentially the same spatially
- Presumed port/underway (“inter-port”) split
- Spatial allocation of underway based on shoreline county boundaries
 - based on waterway lengths for segments in each county

Modified STEEM Methodology

- Port, near-port, and underway blended
- Foreign traffic cargo loading information only
 - exceptions: domestic-domestic, specific ports
- Multiple modes of operations
 - hotelling, maneuvering, RSZ, cruise
- Empirical shipping routes:
 - International Comprehensive Ocean-Atmosphere Data Set (ICOADS), and the Automated Mutual-Assistance Vessel Rescue (AMVER) system
- Draft TSD includes discussion of port and underway inventory development and blend/merge techniques
 - certain port replacements
 - activity growth by regions

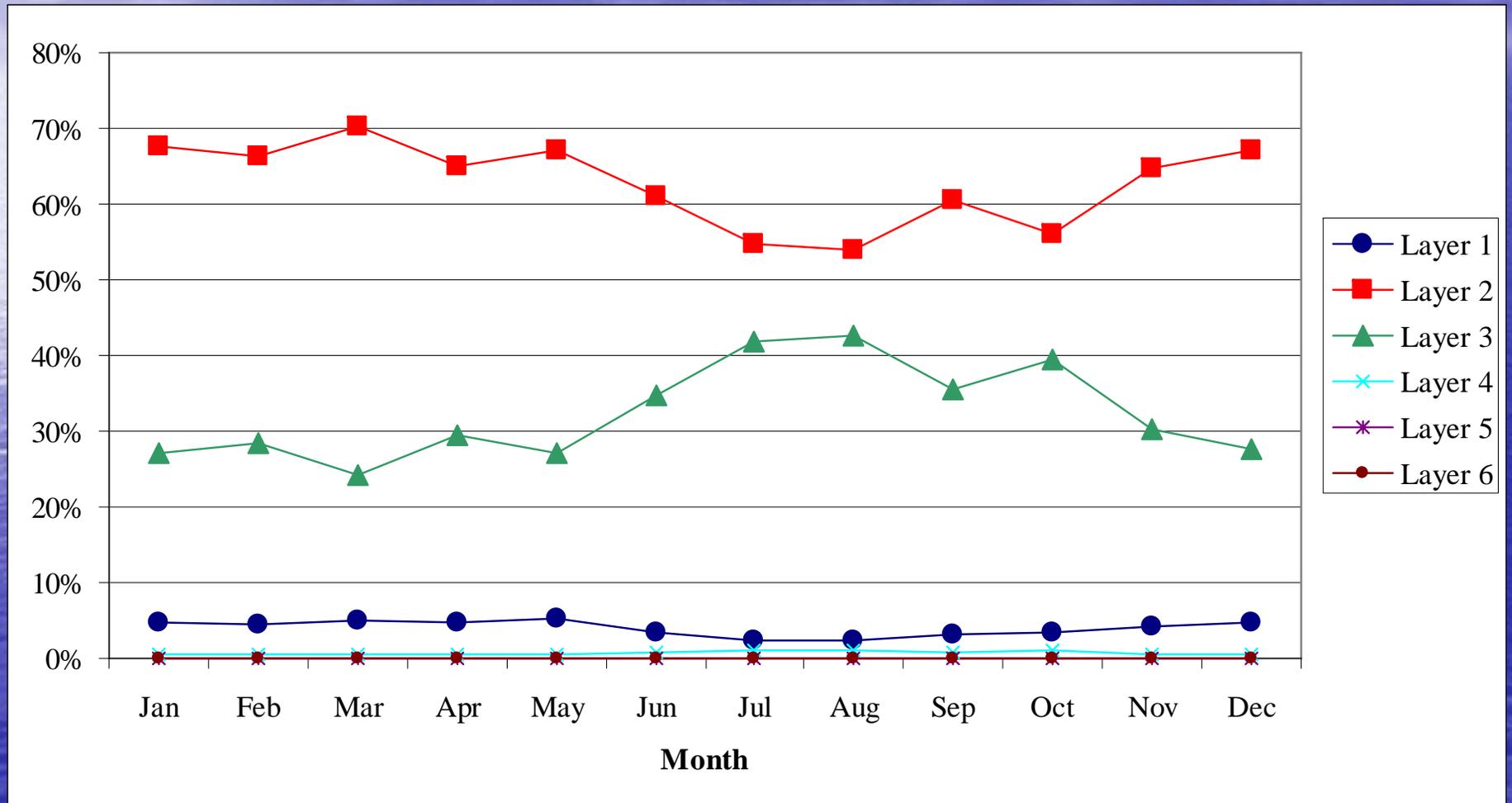
Converting Modified STEEM C3 to SMOKE ORL Format

- Resolution approximately 4km x 4km (Equidistant Cylindrical)
 - 3,750 columns & 2,000 rows (most of NW hemisphere Pacific through western Atlantic oceans)
- ASCII raster format, 1 file / pollutant
 - no FIPs or latitude/longitudes
- ArcGIS® to build cross-reference
 - ASCII raster imported as Grid coverages containing column/rows (colrow variable)
 - ArcInfo® SAMPLE command extracted coordinates and FIPS for each "grid cell"
- Use of US shipping lane polygon shapefile to assign US FIPS to modified STEEM emissions for:
 - inland waterways and lakes
 - ports
 - through the Exclusive Economic Zone (EEZ) up to 200nm offshore or international water boundaries

Converting Modified STEEM C3 to SMOKE ORL Format (cont.)

- Approach using EEZ boundaries into Federal waters overestimates county-level aggregate estimates
- SMOKE Point ORL Format
 - Discrete locations
 - SCCs not resolved between port/underway
 - Stack parameters
- Stack Parameters based on compromise set from observations and studies (Corbett, 2007)
 - Stack Height: 65.62 (feet), 20 (meters)
 - Stack Diameter: 2.625 (feet), 0.8 (meters)
 - Stack Velocity: 82.05 (feet/sec), 25 (meters/sec)
 - Stack Gas Exit Temperature 539.6 (°F), 282 (°C)
- Results in more elevated C3 emissions vs. NEI

SO2 Modified STEEM C3 Emission Allocation by Vertical Layer* and Month

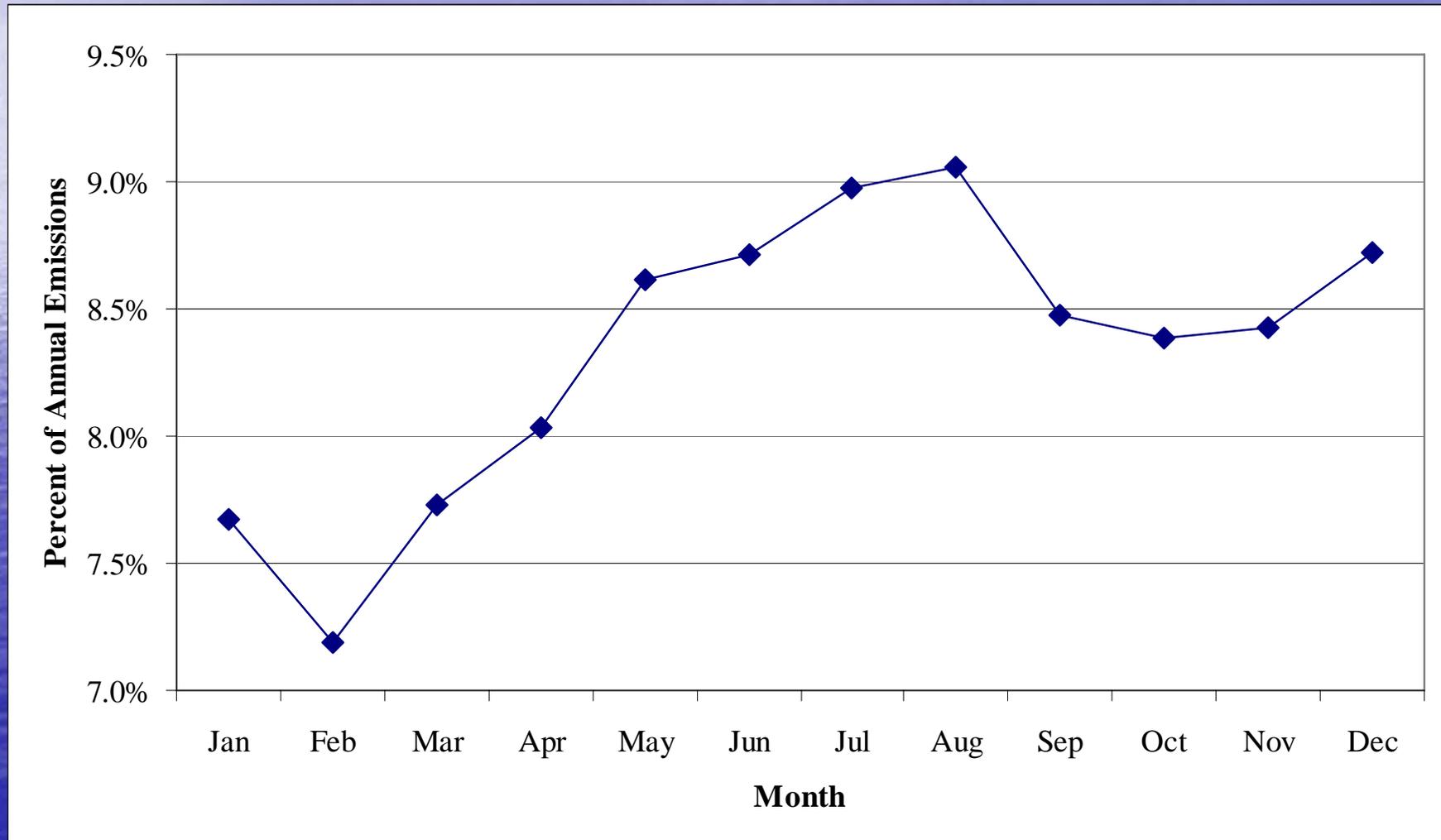


* Layer 1 ~125 ft, Layer 2 ~253 ft, Layer 3 ~505 ft

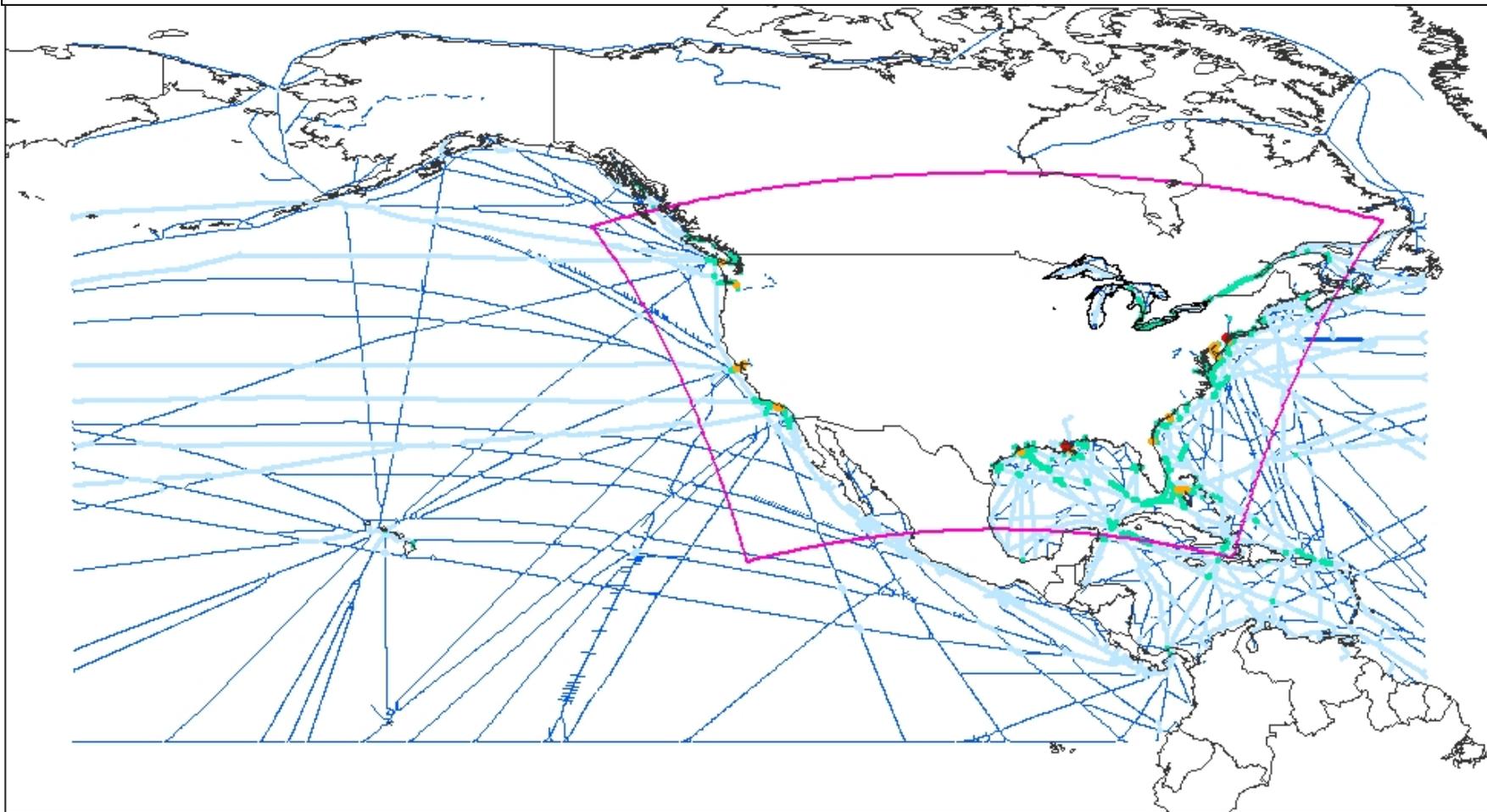
Converting Modified STEEM C3 to SMOKE ORL Format (cont.)

- Window domain to just CMAQ 36-km domain and Alaska and Hawaii
- Assign dummy non-US FIPS and 1 fix to FIPS
- Emission factors for HAPs based on VOC, PM10, or PM2.5
- Similar Speciation including PM2.5 split (SCC created for "All" residual fuel -C3 surrogate) and uniform Temporal Allocation by hour and day-of-week
 - exception: monthly allocation of Modified STEEM inventory vs. uniform in NEI
- Modified STEEM Monthly Allocation based on average monthly variation in STEEM inventory
 - similar to global shipping activities
 - simple uniform domain-wide adjustment, no spatial shift in shipping lane segments

Monthly Distribution of Modified STEEM C3 Emissions



2002 Detailed Modified STEEM NOx C3 Emissions [tons/year]



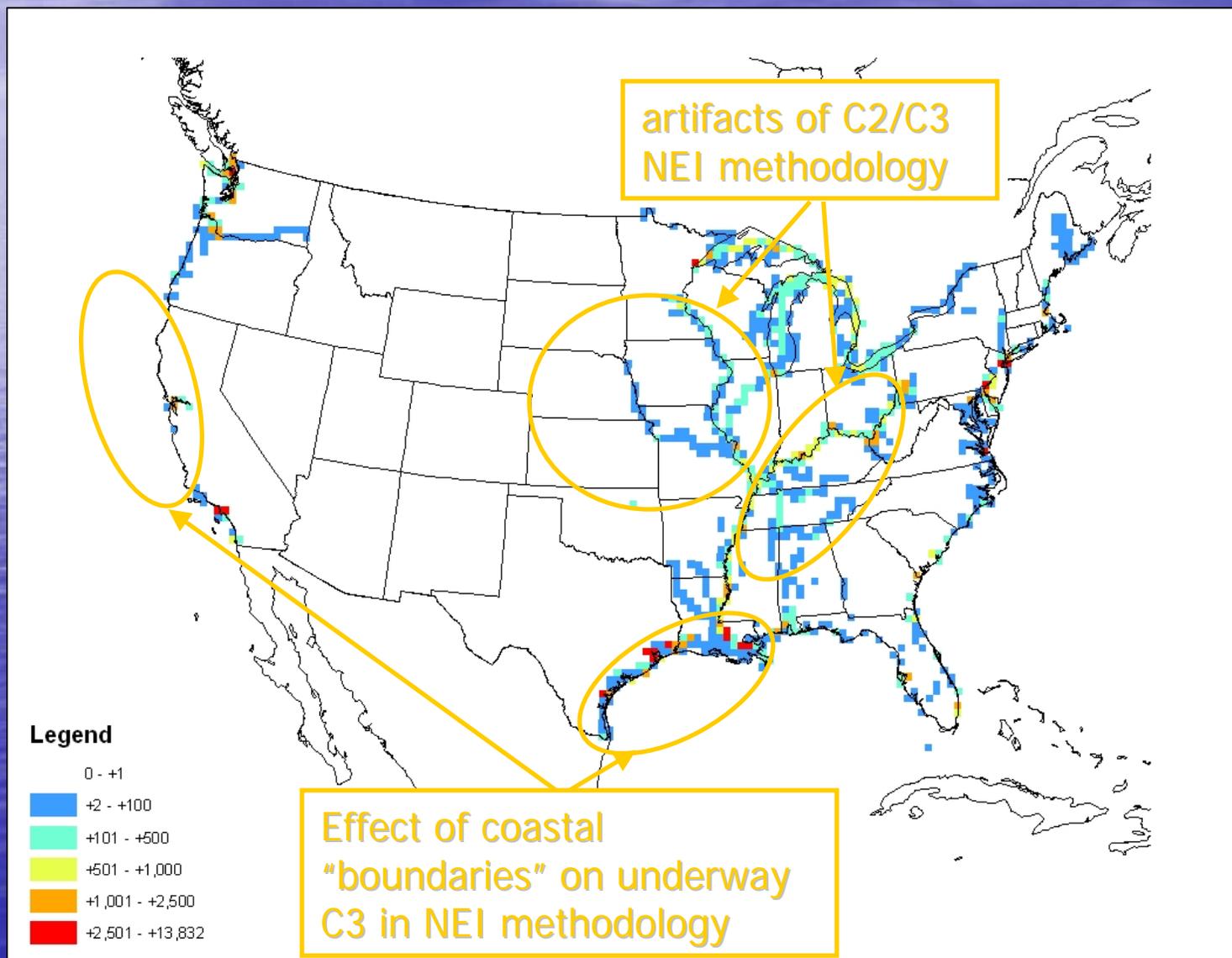
- CMAQ 36km domain
- 0-1
- 1-10
- 10-100
- 100-1,000
- 1,000-2,500

Contiguous U.S. Contribution of NEI and Preliminary Modified STEEM* C3 Emissions to Total for 2002 and 2020

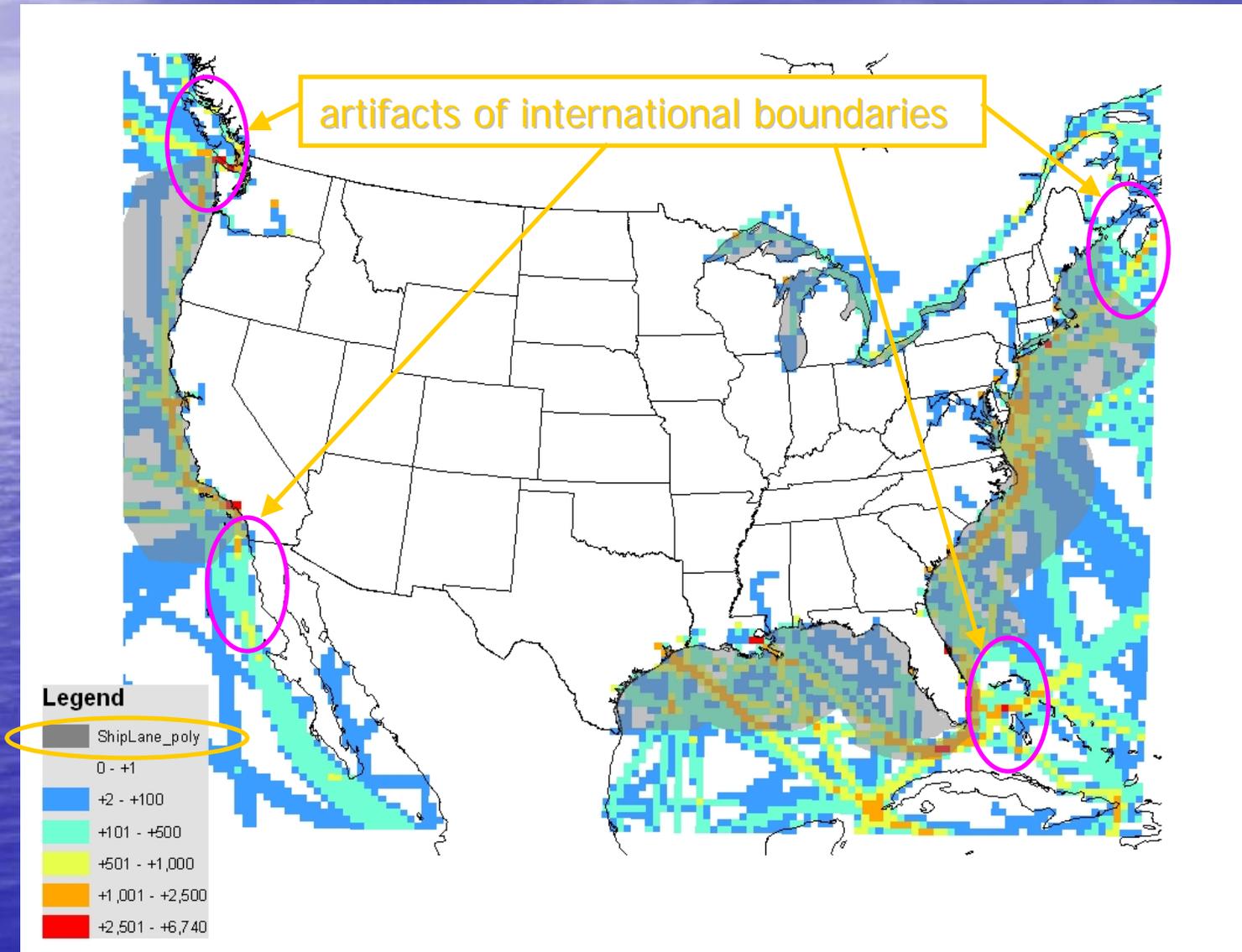
Inventory	NOx	SO2	PM2.5
2002 C3 Draft Modified STEEM	600,000	370,000	48,000
2002 C3 NEI	240,000	150,000	13,000
2002 US Total (w/ Modified STEEM C3)	21,190,000	14,870,000	12,850,000
2002 Modified STEEM C3 % of Total	2.8%	2.5%	0.4%
2020 C3 Draft Modified STEEM	1,100,000	760,000	90,000
2020 C3 NEI	390,000	240,000	22,000
2020 US Total (w/ Modified STEEM C3)	11,620,000	8,690,000	12,750,000
2020 Modified STEEM C3 % of Total	9.5%	8.7%	0.7%

*** Caveat: Spatial extent of underway emissions is much greater in STEEM**

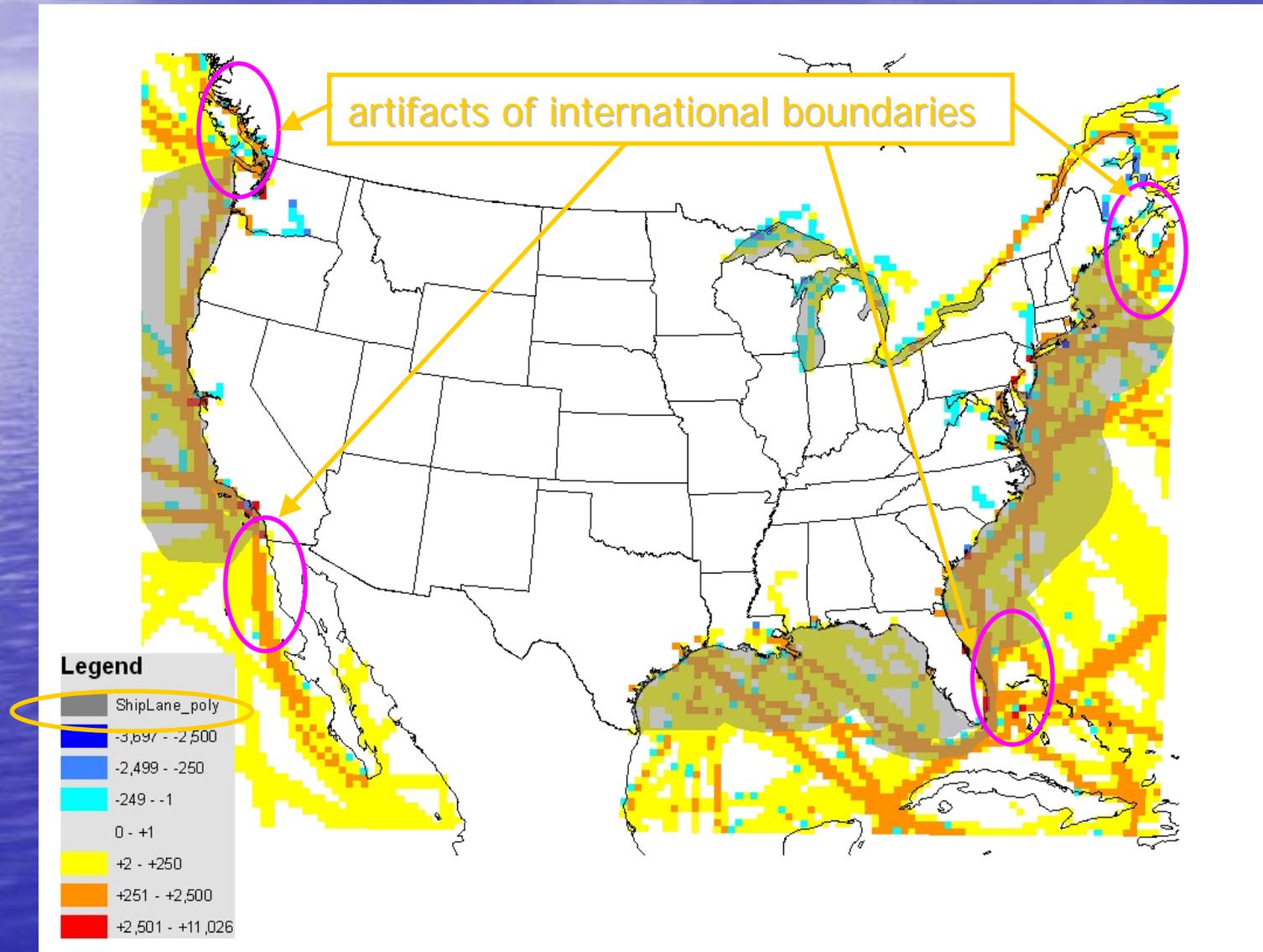
2002 36-km Gridded NEI C3 NOx Emissions [tons/year]



2002 36-km Draft Gridded Modified STEEM C3 NOx Emissions [tons/year]



2002-2020 Increase in 36-km Draft Modified STEEM C3 NOx Emissions [tpy]

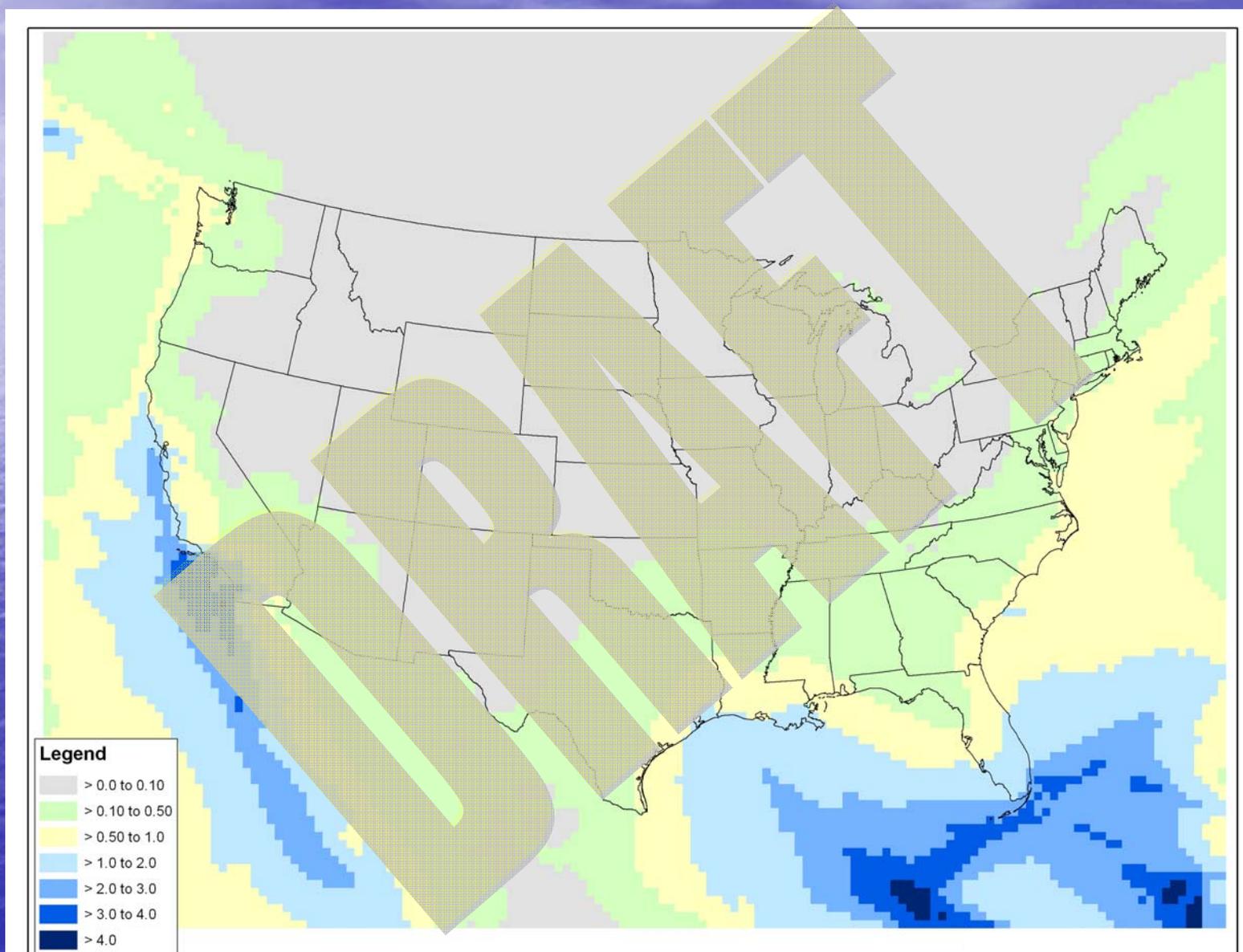


Air Quality Modeling Impacts* of Preliminary Modified STEEM C3 Emissions in 2020

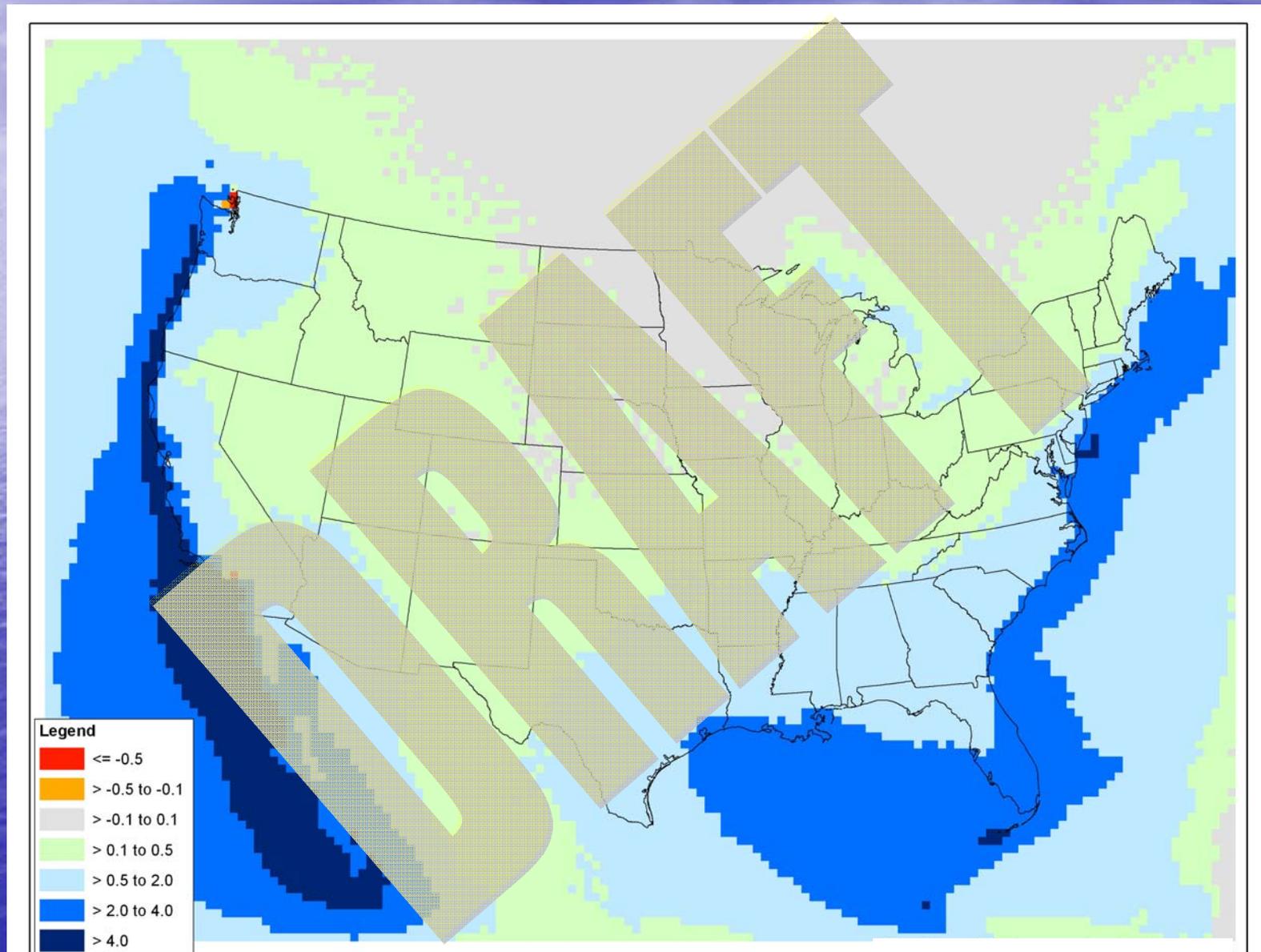
- 2 CMAQ annual runs at 36-km resolution
 - 2020 Base with Modified STEEM C3 Emissions
 - 2020 Base without these emissions
- PM_{2.5} impacts over 0.5 ug/m³ over parts of CA, FL, Gulf & East Coasts, NJ, NYC and Seattle
 - smaller but still significant downwind and transport impacts in northwest, south and east
- 8-hour ozone design values are reduced as much as 2-4 ppb in parts of the northeast U.S., southeast TX, and southern CA

*** Impacts are based on draft STEEM modeling and complete elimination of C3 –NOT intended to illustrate any particular control case!!**

Contribution of all Preliminary Modified STEEM C3 Emissions in Modeling Domain to 2020 Annual $PM_{2.5}$ Design Values ($\mu g/m^3$)



Contribution of all Preliminary Modified STEEM C3 emissions in Modeling Domain to 2020 8-hour Ozone Design Values (ppb)



Conclusions

- NEI and Gridded STEEM C3 Inventories are radically different in methodology and format for emissions processing
- C3 emissions are a significant emissions source of NO_x and SO₂, less so for PM
- Impacts on air quality estimates for ozone and PM are potentially significant as well, particularly on a local scale

Disclaimer

- This paper has not been subject to EPA's required peer and policy review, and therefore does not necessarily reflect the views of the Agency. No official endorsement should be inferred.

Questions?

