ATMOSPHERIC DEPOSITION OF NITROGEN TO TAMPA BAY: MAGNITUDE, SOURCES, AND TRENDS

Presented by
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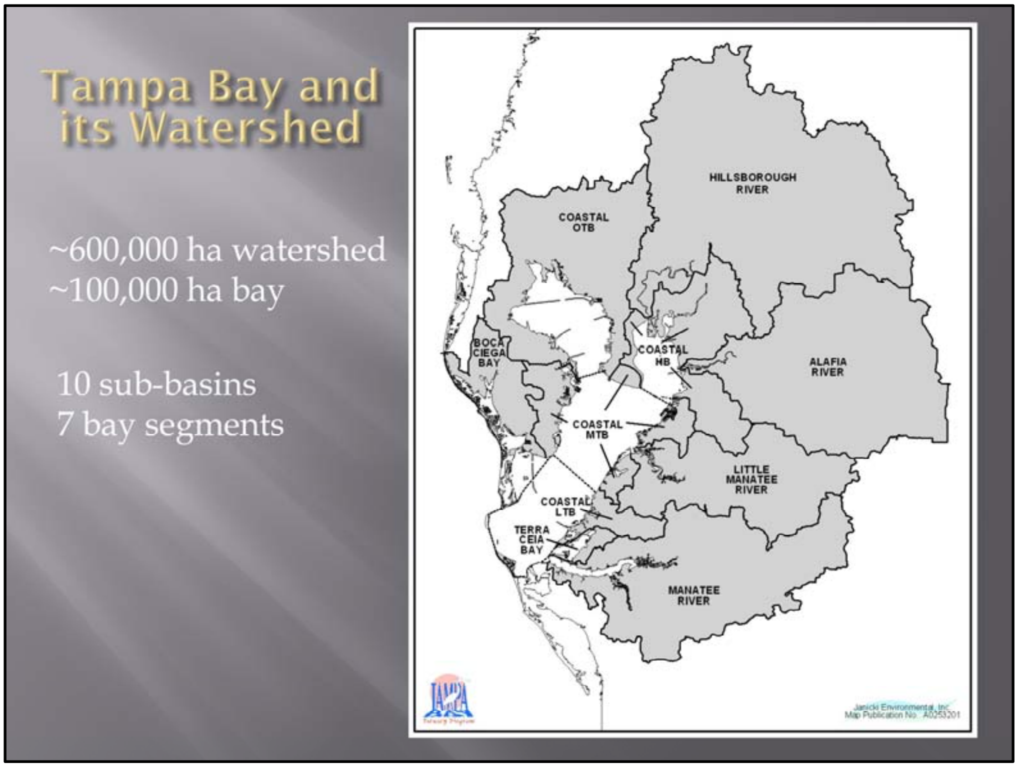
This presentation features the Community Multiscale Air Quality (CMAQ) modeling work of Robin Dennis and Jeff Arnold (see citation below), which was accomplished as part of Bay Region Atmospheric Chemistry Experiment (BRACE) and is central to a synthesis of BRACE results. CMAQ modeling gives us insight into the spatial and temporal distributions of N deposition that are difficult to gain through monitoring alone.

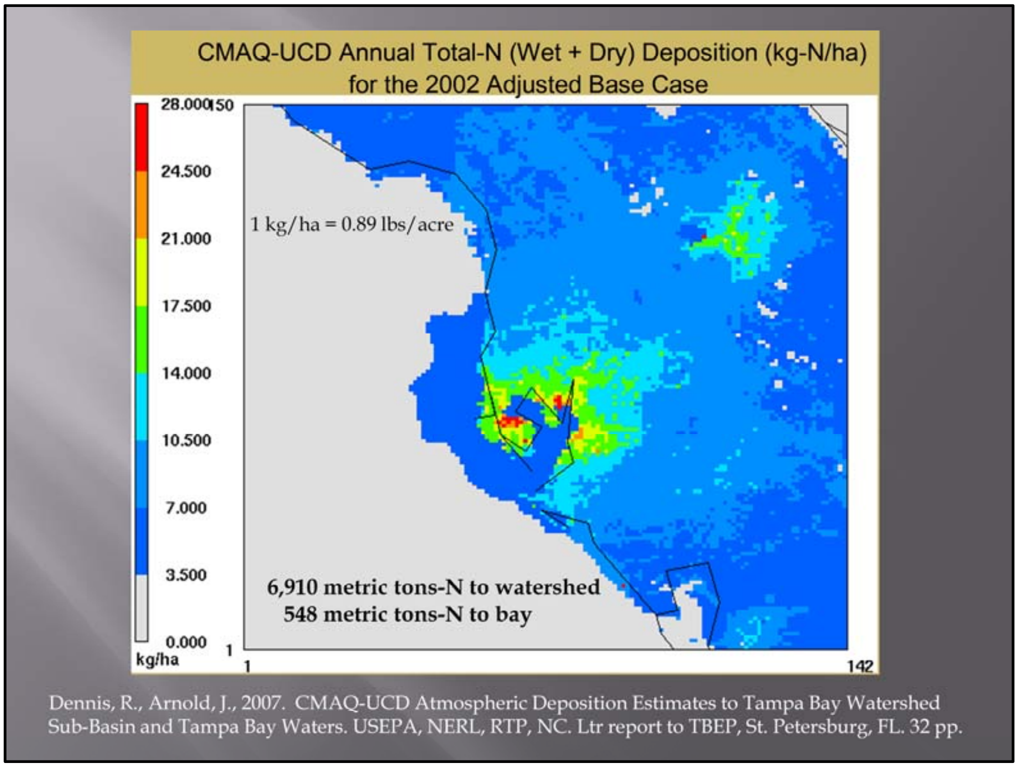
Dennis, R., Arnold, J., 2007. CMAQ-UCD Atmospheric Deposition Estimates to Tampa Bay Watershed Sub-Basin and Tampa Bay Waters. USEPA, NERL, RTP, NC. Ltr report to TBEP, St. Petersburg, FL. 32 pp.

A digital copy of this report is available for download from the Tampa Bay Estuary Program website as a technical document.

In addition to the CMAQ modeling of Dennis and Arnold (2007), this presentation includes total nitrogen loading estimates published by Amy Poe and staff at Janicki Environmental and an estimate of a watershed land-to-water transfer coefficient for atmospherically deposited nitrogen made by Curtis Pollman, formerly of Tetratech.



This graphic reflects the sub-basins and bay segments used by Dennis and Arnold (2007) for their CMAQ modeling.



CMAQ v4.4 was run with University of California Davis (UCD) aerosol module (a version of aerosol inorganics model or AIM) The UCD aerosol module simulates the dynamics of nitric acid –sea salt interactions, as these interactions influence nitrogen deposition rates in peninsular Florida. Grid cells sizes were 32-km across continental US; 8-km across the southeastern US; and 2 km across Tampa Bay and its watershed. Meteorology was prepared with Penn State/NCAR MM5 v3.6; emissions were developed from the 1999 National Emissions Inventory (NEI), updated to 2002 for mobile and power plant sources and to 2001 for all other sources. Ten months of hourly runs were modeled: 7 months in 2002 (Apr, May, Jul, Aug, Sep, Oct, Nov) and 3 months in 2003 (Jan, Feb, Mar); months were chosen such that each month had close to the 15-yr avg rainfall. Ammonia emissions were adjusted upward to account for Florida's warmer wintertime temperatures; ammonia deposition rates were adjusted downward and reported by Dennis and Arnold (2007) as the "adjusted base case". Species modeled included reduced N: ammonia and ammonium; and oxidized N: nitrogen oxide, nitrogen dioxide, nitrous acid, nitric acid, dinitrogen pentoxide, nitrate, peroxyacetyl nitrate. Uncertainties were typical for this type of modeling and were estimated for N deposition rates as within a factor of 2 at any one location. Results may be biased high due to choice of parameters for calculating dry deposition velocities for some N species.

N deposition rates as shown by the above map ranged up to 28 kg-N/ha, which is a rate associated with low to moderate air pollution when compared with rates seen around the globe. Note the steep gradients in urban and industrial land use/land cover sectors.

Atmospheric Deposition of N to Tampa Bay: Magnitude

- Pollman and Poor (2003) estimated that 18% of N atmospherically deposited to Tampa Bay's watershed was transferred to the bay.
- Poe et al. (2005) estimated in 2002 direct atmospheric and total N loading to Tampa Bay of 840 metric tons and 3,400 metric tons, respectively.

Pollman, C., Poor, N. D., 2003. Export of Atmospherically Derived Nitrogen in the Tampa Bay Watershed. American Geophysical Union (AGU) Fall Meeting, San Francisco, CA, 8-12 December.

Poe, A., Hackett, K., Janicki, S., Pribble, R., Janicki, A., 2005. Estimates of Total Nitrogen, Total Phosphorus, Total Suspended Solids, and Biochemical Oxygen Demand Loadings to Tampa Bay, Florida: 1999-2003, Final Report, March 2005. Tampa Bay Estuary Program Technical Publication #02-05, St. Petersburg, FL, pp. 374.

Indirect deposition: 6,910 metric tons-N/year
Direct deposition: 548 metric tons-N/year

Note that large uncertainties exist for estimates on both total N loading to Tampa Bay and on land-to-bay transfer rates for atmospheric deposition.

Atmospheric Deposition of N to Tampa Bay: Magnitude

- Calculate direct + indirect N loading from atmosphere: 6,910 x 0.18 + 548=1,790 metric tons
- Adjust 2002 total N loading rate for the CMAQ-modeled direct atmospheric N loading rate (3,400 – 840 + 548 = 3,110 metric tons)
- For 2002, CMAQ-modeled contribution of atmospheric N loading to total N loading was 1,790/3,110 = 58%: 18% direct and 40% indirect

CMAQ-modeled estimate is mid-range of previous estimates. Lowest estimate for direct plus indirect modeling to Tampa Bay was 1,100 metric tons N/year from CALPUFF modeling by Poor (2008), where sources modeled represented only those in central peninsular Florida. Highest estimate was 3,040 metric tons N/year from bulk deposition sampling by Dixon et al (1996). Approaches used to date for estimates include bulk deposition sampling, land use/land cover modeling, air and rainwater quality monitoring, air pollution modeling, and wet/dry ratios applied to N in rainfall.

Atmospheric N Deposition to Watershed Sub-Basins

Watershed Sub-Basins	% of Watershed Total	% of Atmos. Loading Total	Average Rate, kg/ha
Coastal Old Tampa Bay	12.6%	8.8%	15.5
Alafia River	18.2%	12.6%	11.4
Hillsborough River	29.8%	20.7%	11.9
Coastal Hillsborough Bay	8.7%	6.0%	17.6
Little Manatee River	10.5%	7.3%	13.6
Coastal Middle Tampa Bay	3.0%	2.1%	17.3
Coastal Lower Tampa Bay	1.1%	0.8%	11.9
Terra Ceia	0.2%	0.1%	11.7
Manatee River	12.1%	8.4%	10.0
Boca Ciega	3.9%	2.7%	17.2

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Atmospheric N Deposition to Bay Segments

Bay Segment	% of Bay Total	% of Atmos. Loading Total	Average Rate, kg/ha
Old Tampa Bay	24.6%	7.5%	7.54
Hillsborough Bay	13.3%	4.1%	9.30
Middle Tampa Bay	29.2%	8.9%	6.34
Lower Tampa Bay	20.2%	6.2%	4.83
Boca Ciega Bay	7.0%	2.1%	7.83
Terra Ceia Bay	0.8%	0.2%	9.47
Manatee River	4.9%	1.5%	11.14

Watershed Average Rate: 12. 7 kg-N/ha
Bay Average Rate: 6.7 kg-N/ha

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Direct plus indirect N deposition to Tampa Bay by bay segment (metric tons-N/year):

Old Tampa Bay 292 Hillsborough Bay 777 Middle Tampa Bay 328 Lower Tampa Bay 124 Boca Ciega Bay 87 Terra Ceia Bay 7 Manatee River 177

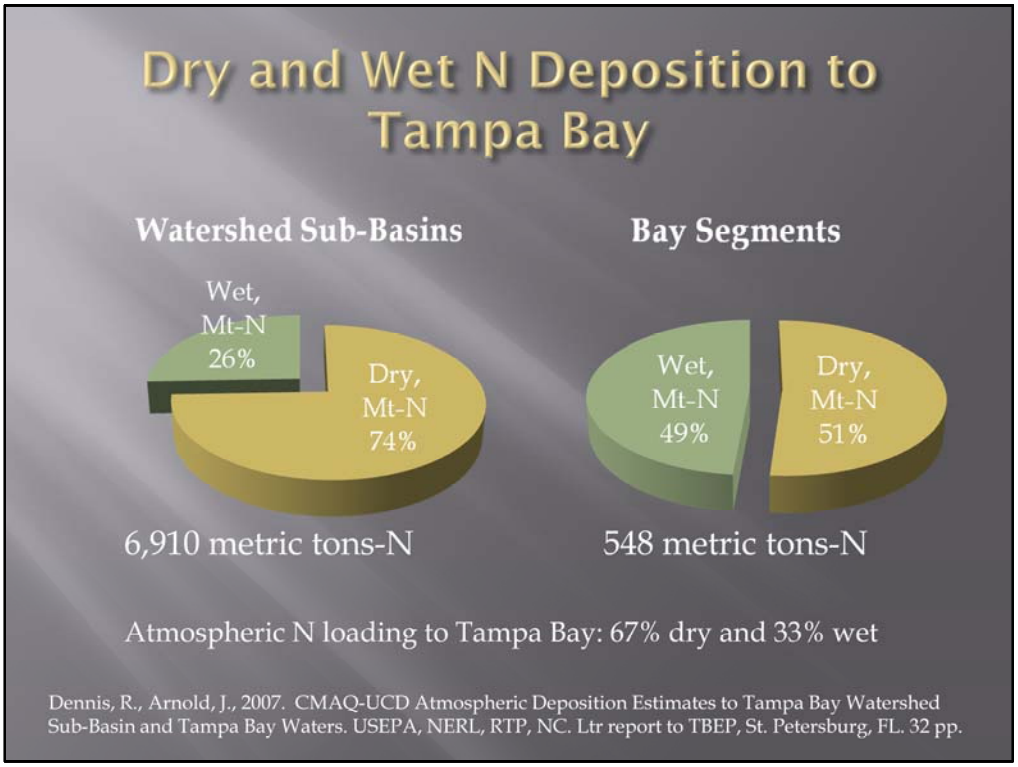
Direct plus indirect N deposition to Tampa Bay by bay segment (% of atmospheric loading total):

Old Tampa Bay 16.3% Hillsborough Bay 43.4% Middle Tampa Bay 18.3% Lower Tampa Bay 6.9% Boca Ciega Bay 4.9% Terra Ceia Bay 0.4% Manatee River 9.9%

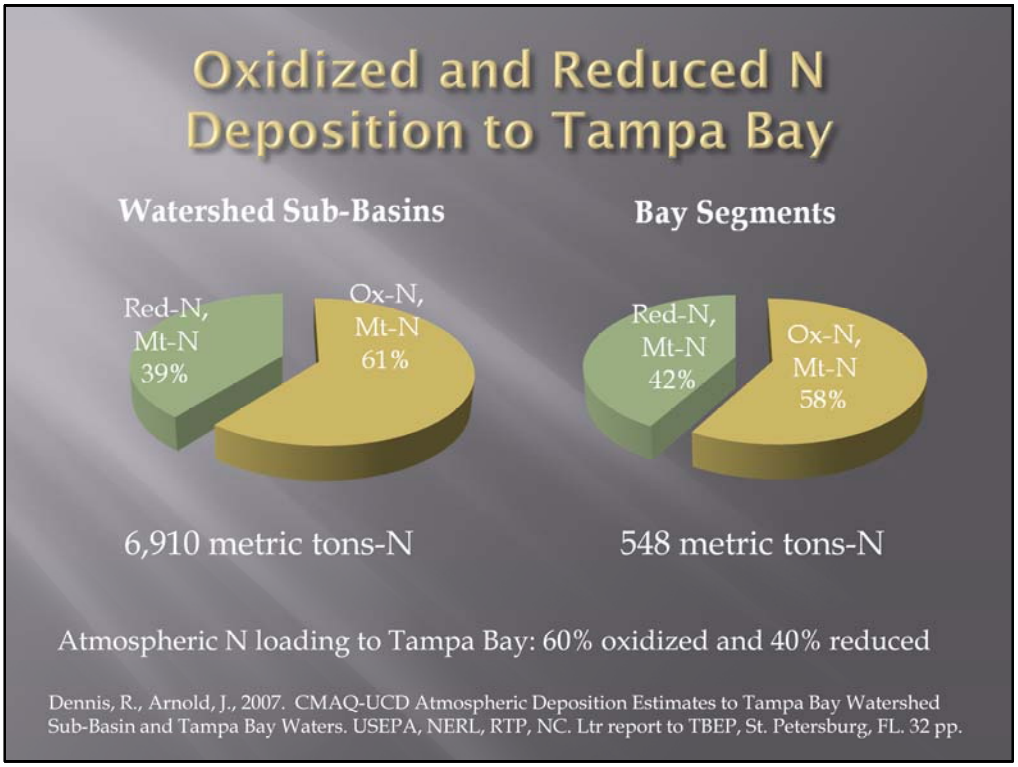
The average N deposition rates to watershed basins including associated bay waters (kg-N/ha):

Old Tampa Bay 13.6 Hillsborough Bay 12.3 Middle Tampa Bay 12.1 Lower Tampa Bay 6.4 Boca Ciega Bay 14.9 Terra Ceia Bay 11.1 Manatee River 10.1

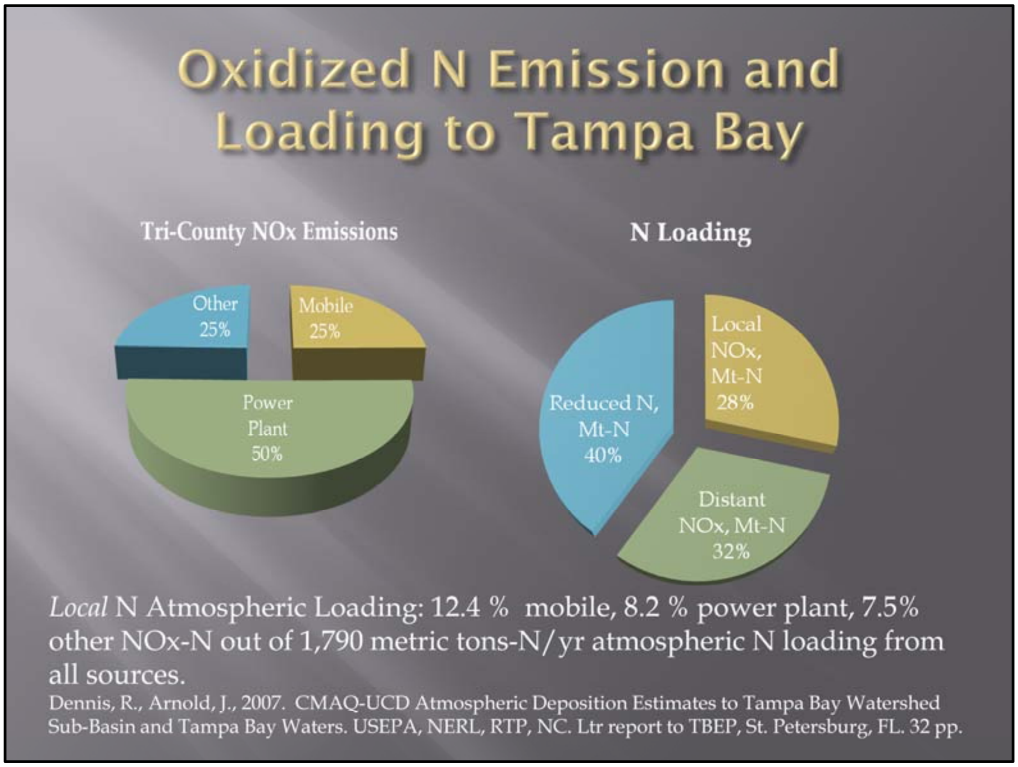
The average N deposition rate to the watershed including the bay is 11.9 kg-N/ha.



Nitrogen oxide plus nitrogen dioxide (or NOX) is poorly water soluble and as such as a lower deposition rate over water than over land. Over land, surfaces are “stickier” relative to NOx. From above graphic, one can see that over water, dry to wet proportions are nearly 1:1 but over land, these proportions are nearly 3:1.



Note that reduced N, that is ammonia and ammonium nitrogen, contribute a substantial portion of the nitrogen delivered to bay waters.



2002 total NOx emissions for Hillsborough, Manatee, and Pinellas Counties were 130,000 metric tons with the split between sources as shown in the graphic above left. The graphic above right shows the relative contribution of local i.e. watershed sources of NOx to oxidized N deposition in the watershed, and the contribution of mobile, power plant, and other sources to total N loading to Tampa Bay.

Reduction in N Deposition Due to Local Power Plant Reconfigurations 2002-2010

- TEC's FJ Gannon re-powered from coal to natural gas; now call Bayside
  - 22,000 metric ton decrease in annual NOx emissions
- TEC's Big Bend plant installed NOx control on stacks
  - 20,000 metric ton decrease in annual NOx emissions

Reduction in N loading to Tampa Bay is 110 metric tons over 8 years, which is about 6% of the 2002 estimate for atmospheric N loading.

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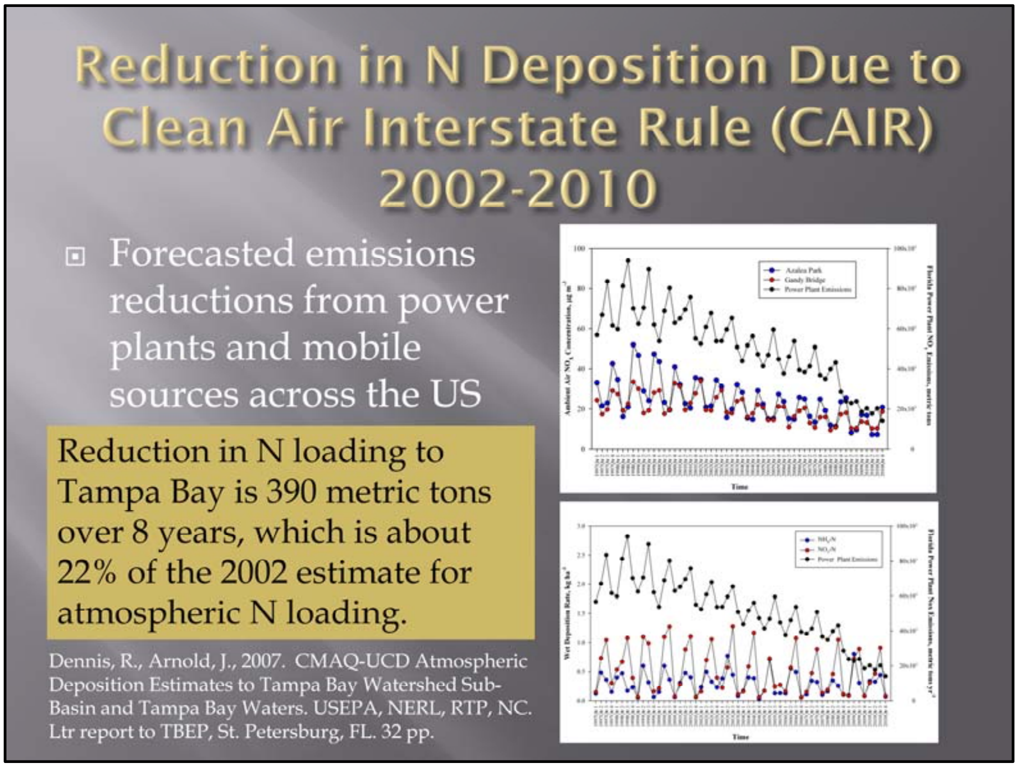

Note that CAIR was recently replaced with Cross-State Pollution Rule.

Emissions inventory for CAIR analysis includes changes in NOx and NH3 emissions associated with not only power plant re-configurations but also Tier 2 Vehicle and Gasoline Sulfur Rule, Heavy Duty Highway Rule, and Non-Diesel Road Rule.

For the fully implemented CAIR, an estimated 6.6 million metric tons of NOx emissions would be removed from the inventory; of this 5.2 million metric tons of NOx emissions would come from eastern US; ammonia emissions are expected to grow by 0.4 million metric tons in the same period. Sources of ammonia include human and animal populations and their associated food and wastes as well as motor vehicle and power plant emissions.

Discussion and Summary

- CMAQ modeling provides important insight on the spatial and temporal distributions of N deposition
- CMAQ –generated estimates of N loading to Tampa Bay are mid-range of those previously published
- Dry deposition of NOx to watershed adds significantly to N loading via indirect atmospheric deposition
- Estimates are rather uncertain

Discussion and Summary

- Local and distant sources of NOx contribute in near equal measure to atmospheric N loading of Tampa Bay
- Mobile sources contribute disproportionately more to N loading than power plants as mobile source NOx emissions are near to the surface
- CAIR (replaced by Cross-State Air Pollution Rule) –mandated NOx reductions have a large influence on atmospheric N loading to Tampa Bay

Conclusions and Recommendations

- Atmospheric N loading is a large fraction of the total N loading to Tampa Bay
- Recommendations:
  - Re-initiate wet deposition monitoring within the watershed
  - Improve estimate of land-to-water transfer of atmospherically-derived nitrogen