

# **2016 Extension of Ammonium and Nitrate Wet Deposition Models for the Chesapeake Bay Watershed and Tidal Waters**

Jeffrey W. Grimm, The Pennsylvania State University

# Objective

Provide updated and refined daily estimates of nitrate and ammonium wet deposition to the Chesapeake Bay Watershed and tidal waters for the period 1984 through 2014 using revised and expanded data sources for:

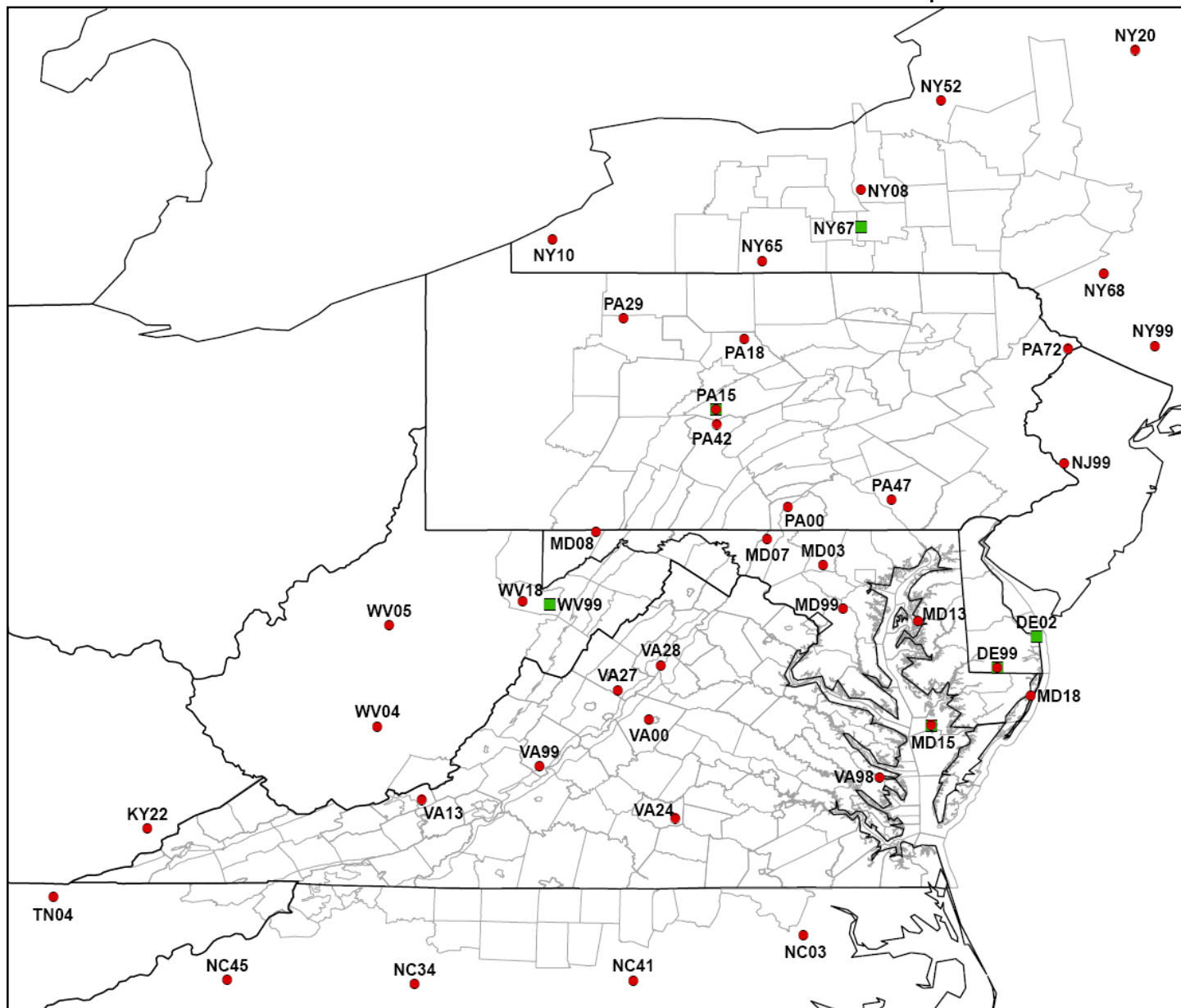
- Land cover and land use
- Rainfall and other meteorological parameters
- Nitrous oxide and ammonia emissions data
- Agricultural and anthropogenic activity including fertilizer application and transportation
- NADP/NTN and AIRMoN Precipitation chemistry observations

Modeling effort will build upon previous models developed by Grimm and Lynch, 2007 for the 1985 through 2005 time span.

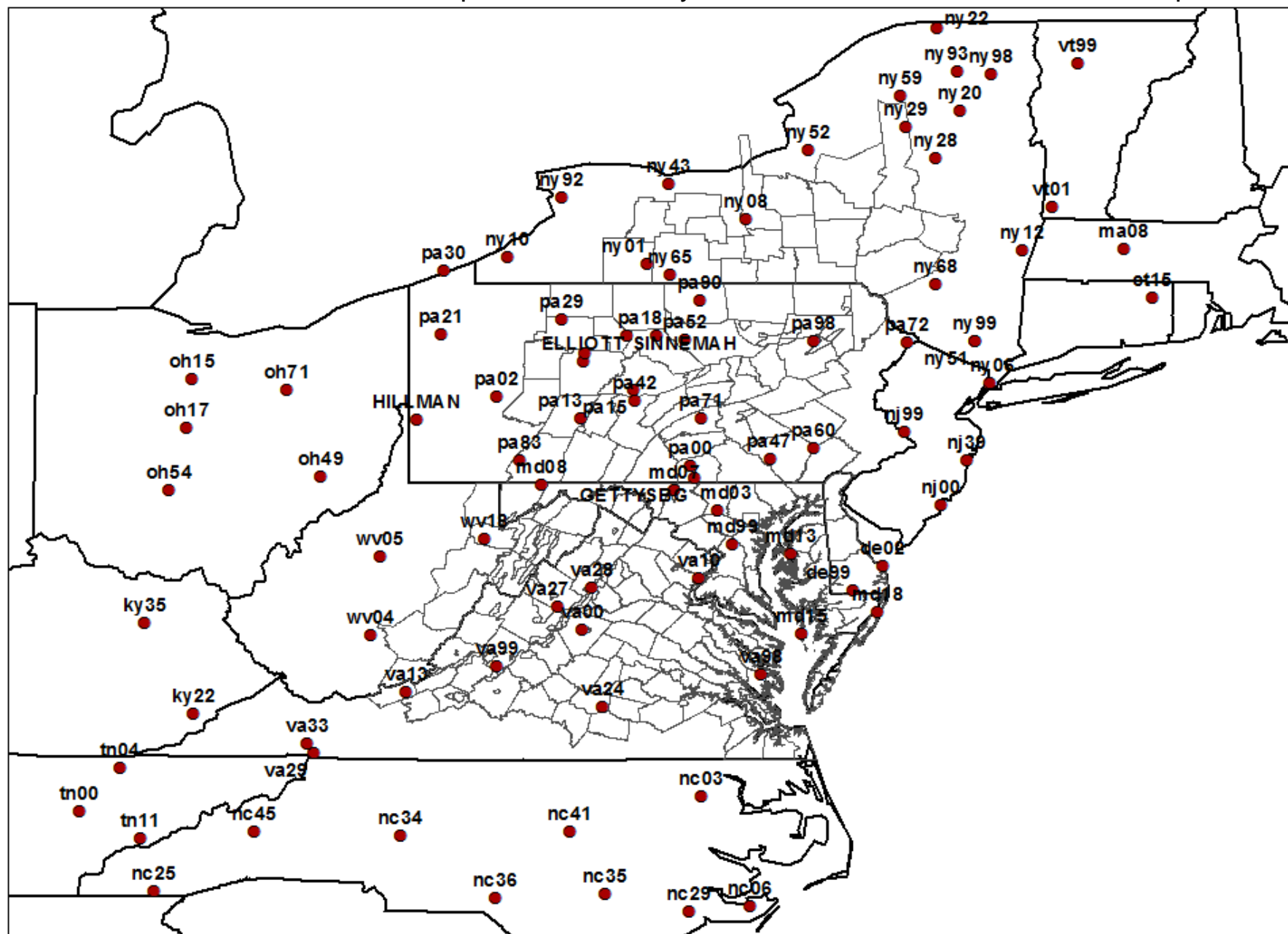
## What is New in the 2016 Update

- Model output time span increased from 1984 through 2005 to 1984 through 2014
- Extended precipitation chemistry data include observations since 2005
- Precipitation and surface meteorological parameters standardized to NLDAS2
- New NLCD data issues for 2001, 2006, and 2011 improve land use characterization during the latter part of modeling period and correct issues in 1992 NLCD.
- Additional emissions data from 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2005, 2008, and 2011 NEI summaries.
- Model verification will be expanded to include representation of trends at long-term precipitation chemistry monitoring stations.

## NTN and AIRMoN Sites Used In Phase 5 Model Development



## NTN, AIRMoN, and PADM Precipitation Chemistry Sites Used in Phase 6 Model Development



# Daily Nitrate Wet-fall Log Concentration Model

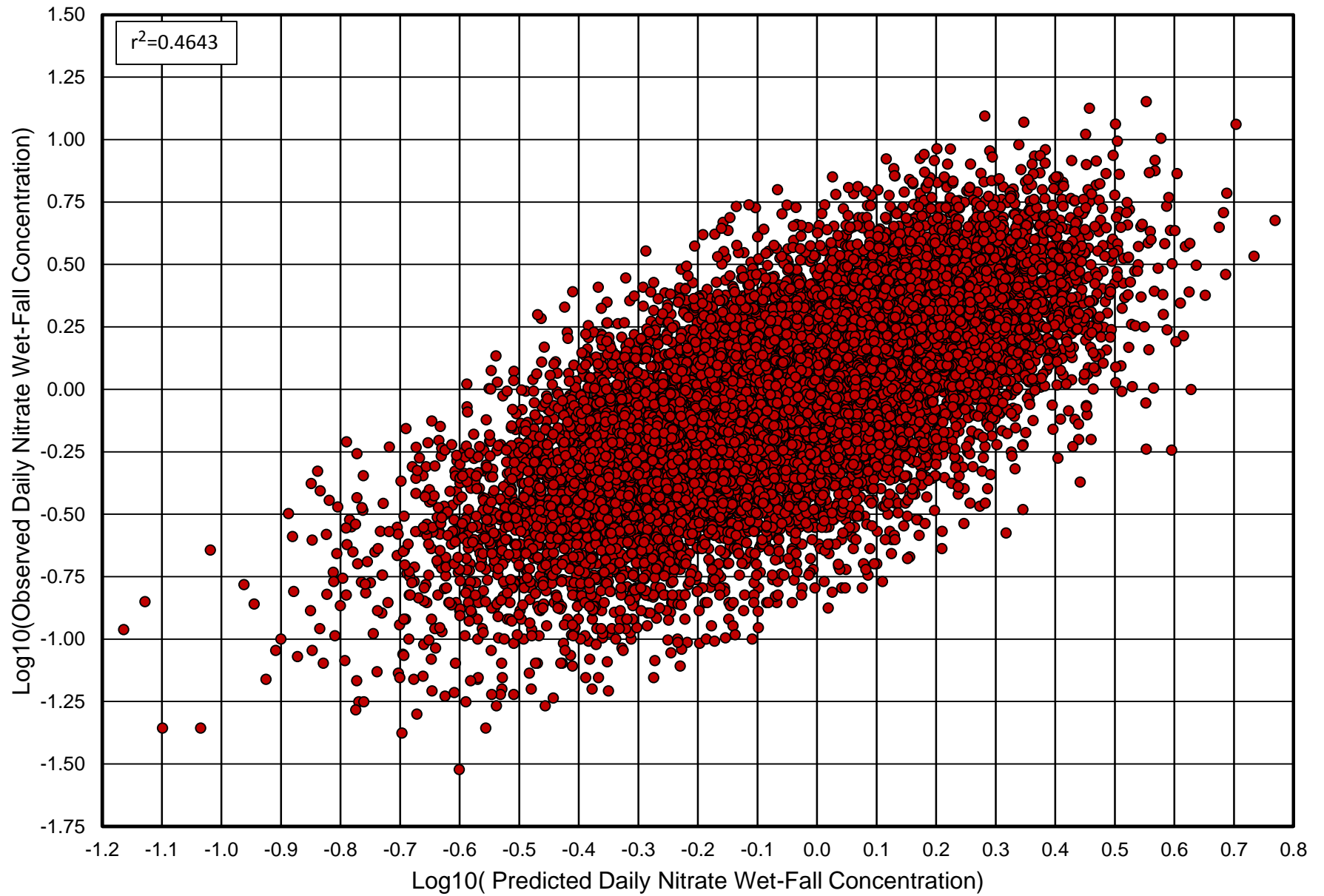
$r^2 = 0.04643$

Parameter	Coeff.	DF	Type 3 SS	p
intercept	-1.76745			<0.0001
daily precipitation	0.09942	1	8.078	<0.0001
sqrt(daily precipitation)	-0.67309	1	77.227	<0.0001
12hr antecedent precipitation	-0.38667	1	6.296	<0.0001
year-1966	-0.06932	1	21.214	<0.0001
sqrt(year-1966)	0.71896	1	17.411	<0.0001
cool season (Sep-Jan)	-0.09324	1	4.762	<0.0001
bimonthly period		5	14.395	<0.0001
jan-feb	0.04122			
mar-apr	0.07892			
may-jun	0.12288			
jul-aug	0.16250			
sep-oct	0.02401			
nov-dec	0.00000			

### Daily Nitrate Wet-fall Log Concentration Model (continued)

Parameter	Coeff.	DF	Type 3 SS	p
log10(facility emissions during 24hr trajectory)	0.12046	1	40.469	<0.0001
sqrt(facility emissions during 6hr trajectory)	0.00185	1	3.827	<0.0001
sqrt(crop land use w/in 10km)	0.10156	1	6.354	<0.0001
log10(residential emissions during 6hr trajectory)	0.04417	1	4.166	<0.0001

Observed vs Predicted Daily Nitrate Wet-Fall Concentration





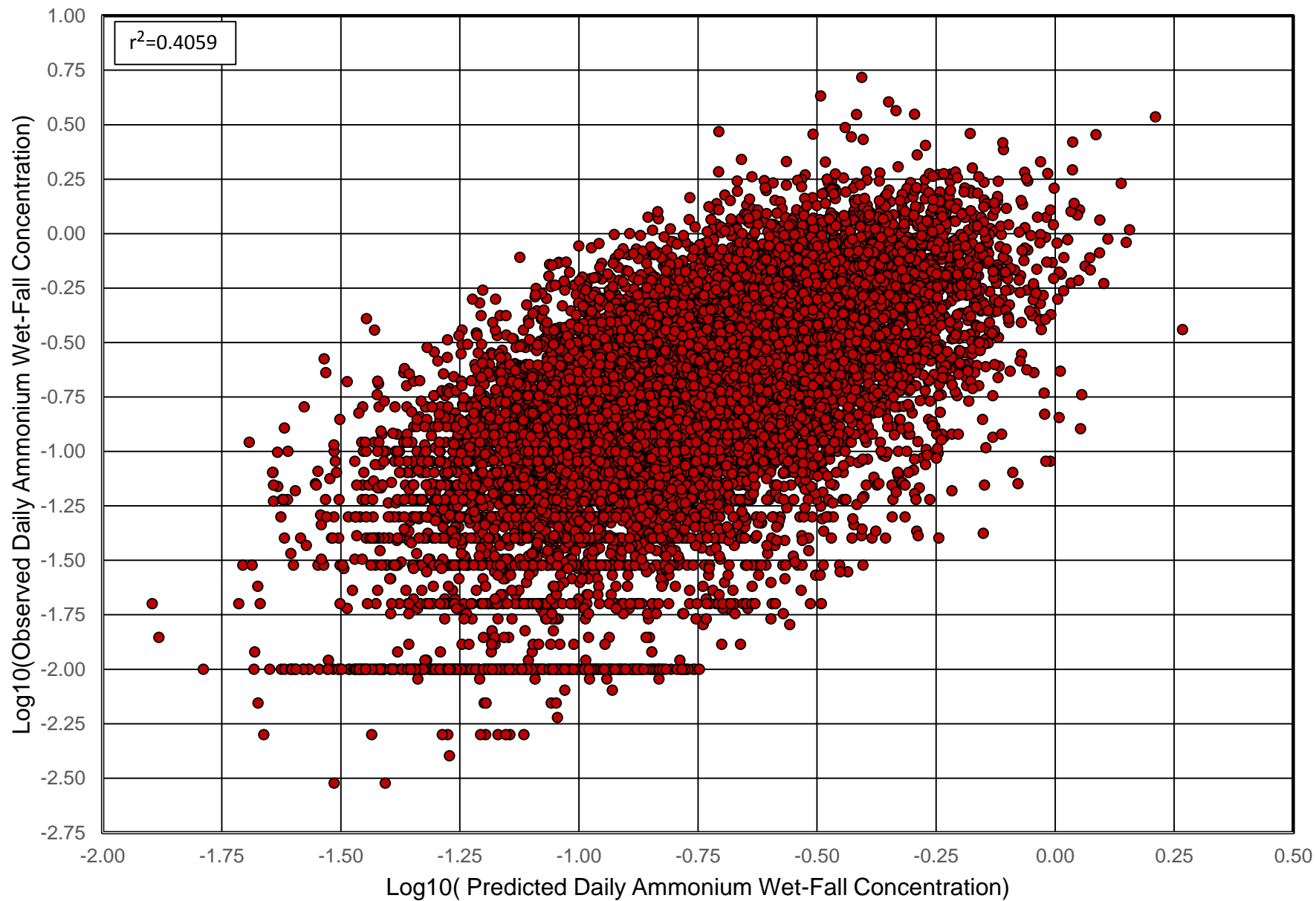
Daily Ammonium Wet-fall Log Concentration Model  
 $r^2=0.4059$

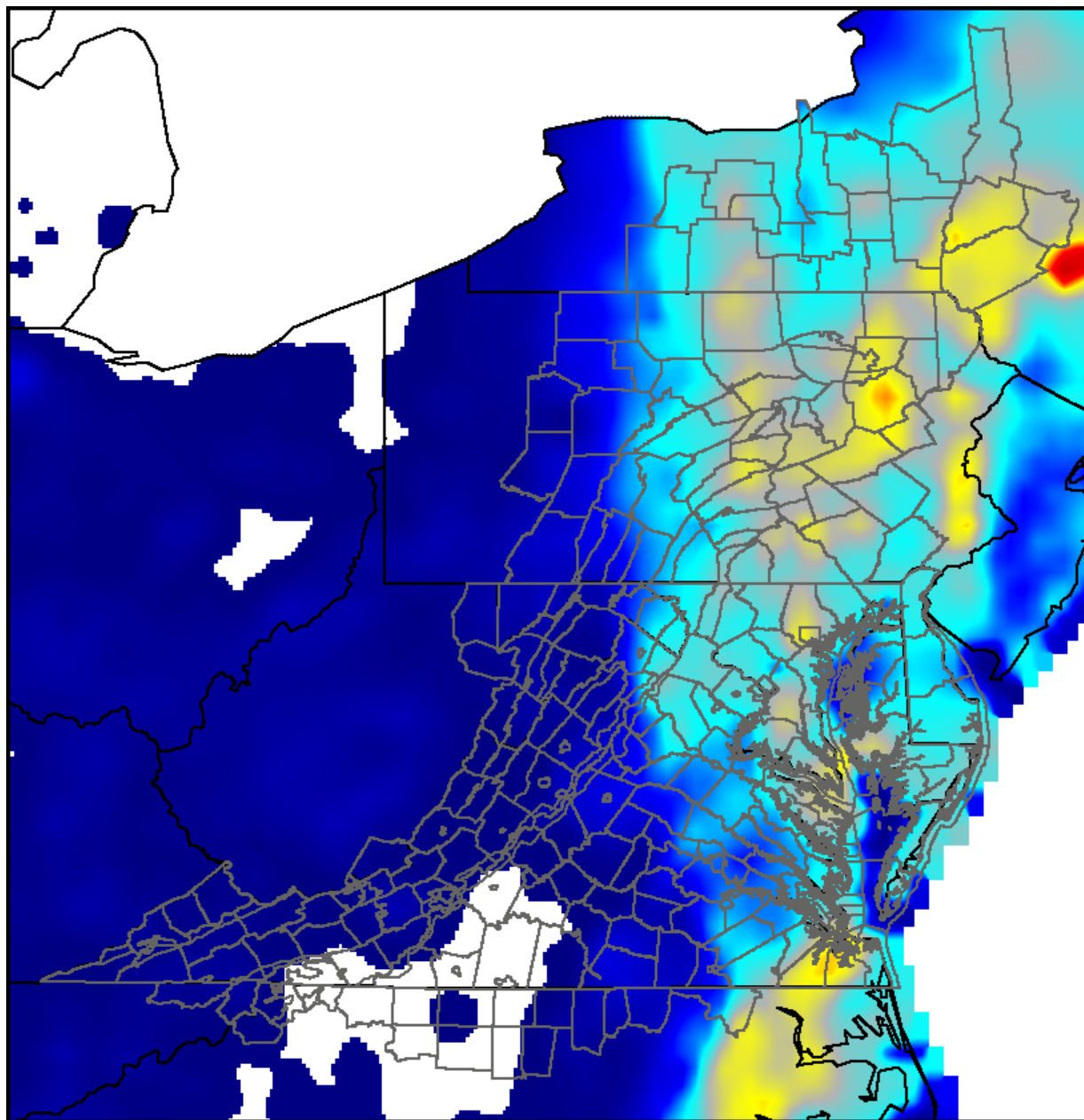
Parameter	Coeff.	DF	Type 3 SS	p
intercept	-1.64642			<0.0001
daily precipitation	0.10827	1	9.522	<0.0001
sqrt(daily precipitation)	-0.73862	1	92.174	<0.0001
24hr antecedent precipitation	-0.16527	1	4.177	<0.0001
year-1977	0.00227	1	2.807	<0.0001
post90 indicator (0 before 1990;1 after)	0.10880	1	8.486	<0.0001
cool season (Sep-Feb)	-0.07119	1	3.053	<0.0001
bimonthly period		5	212.987	<0.0001
jan-feb	0.02073			
mar-apr	0.27924			
may-jun	0.38368			
jul-aug	0.34623			
sep-oct	0.07014			
nov-dec	0.00000			

# Daily Ammonium Wet-fall Log Concentration Model (continued)

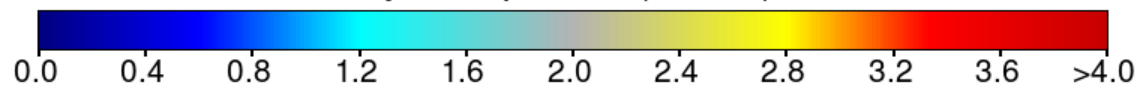
Parameter	Coeff.	DF	Type 3 SS	p
sqrt(crop land use w/in 64km)	0.23702	1	17.800	<0.0001
sqrt(livestock production w/in 64km)	0.26029	1	4.818	<0.0001
sqrt(livestock emissions during 24hr traj.)	0.01161	1	28.882	<0.0001
log10(livestock emissions during 3hr traj.)	0.05285	1	5.556	<0.0001
sqrt(heavy residential land use w/in 48km)	0.30885	1	3.008	<0.0001
transportation land use w/in 64km	0.98407	1	3.793	<0.0001
lat	0.02063	1	26.900	<0.0001

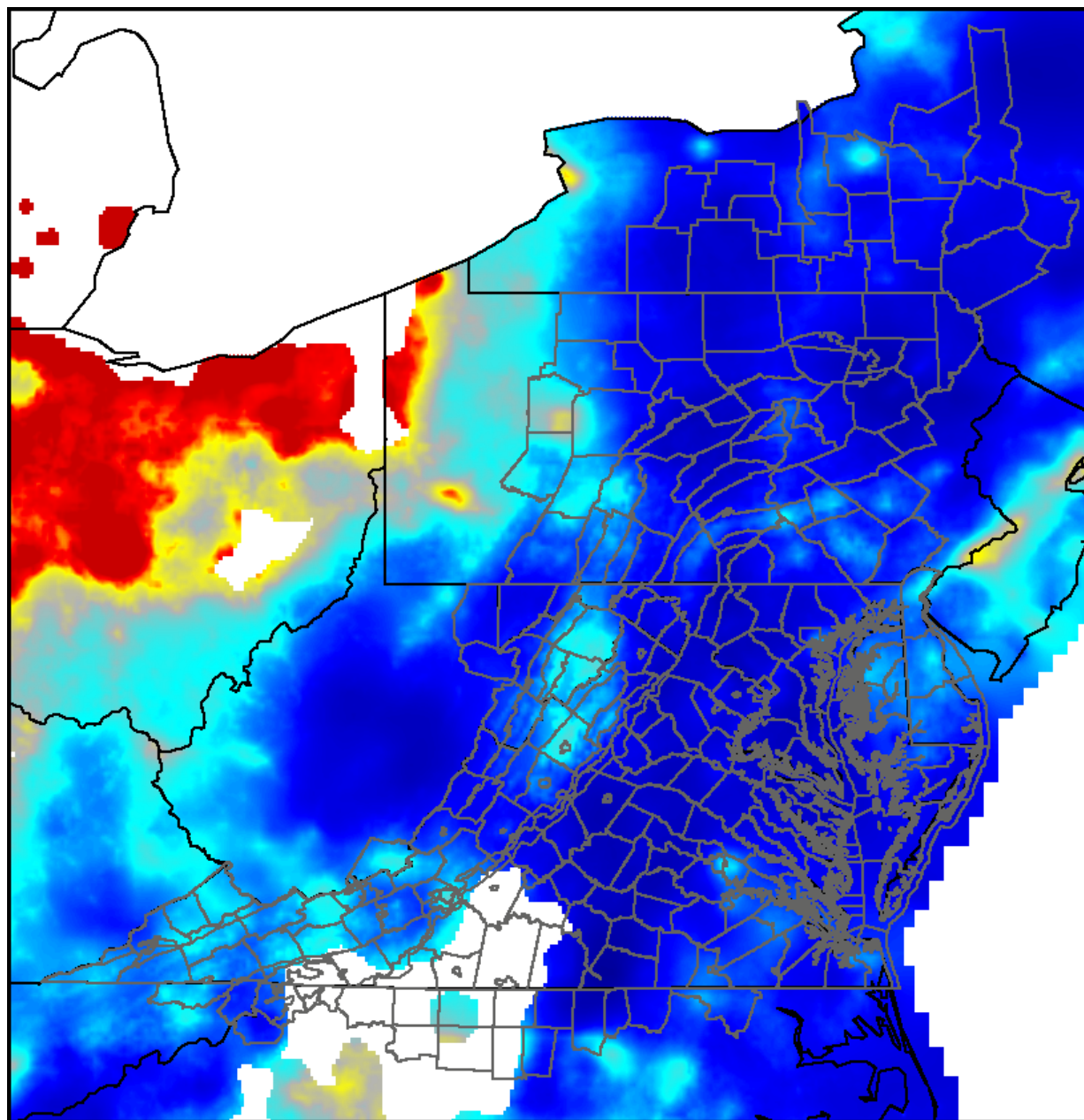
Observed vs Predicted Daily Ammonium Wet-Fall Concentration



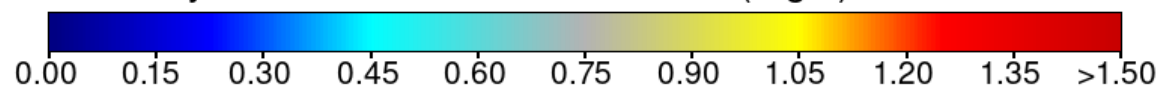


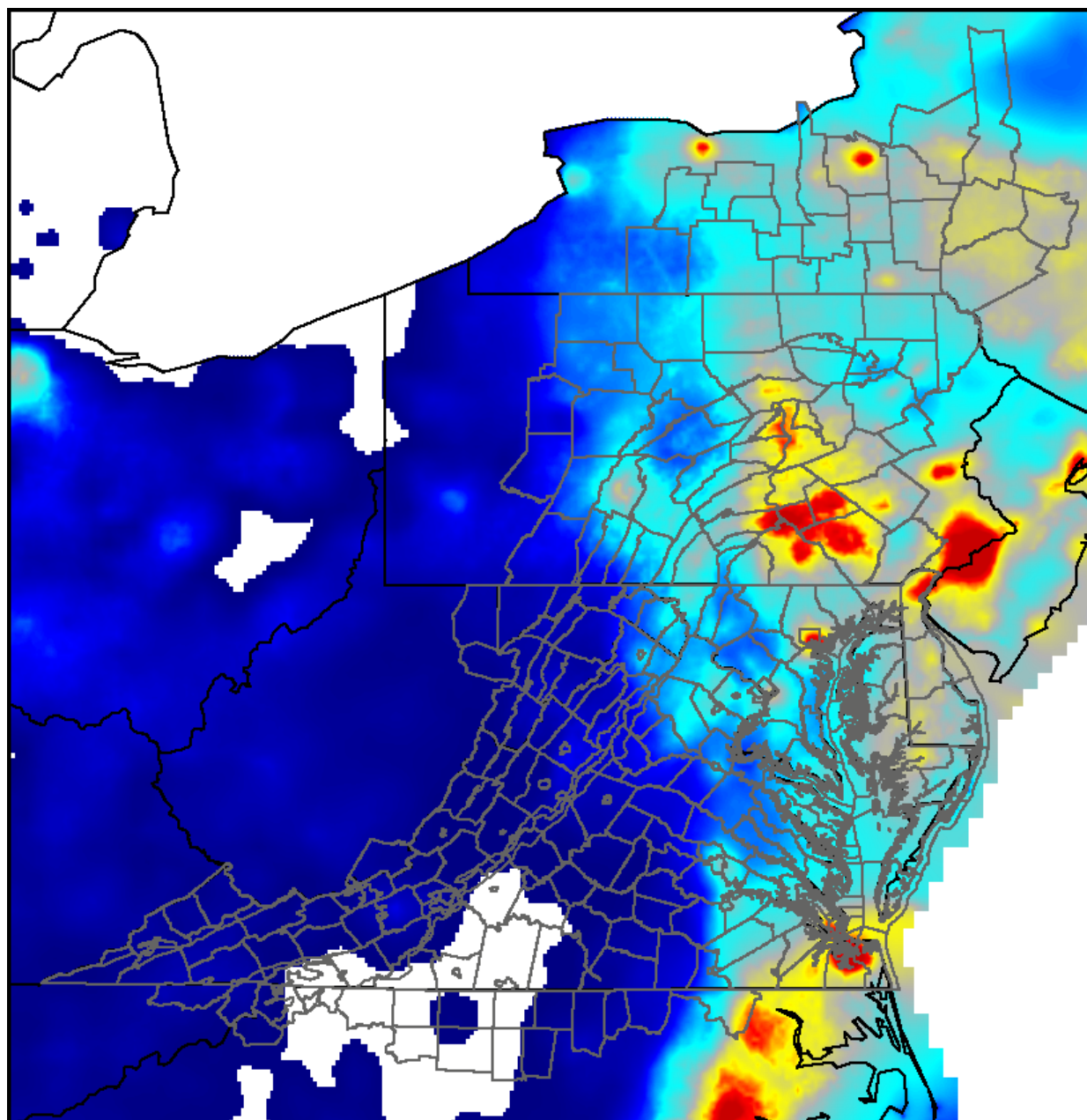
NLDAS2 Daily Precipitation (Inches): 2014-05-16



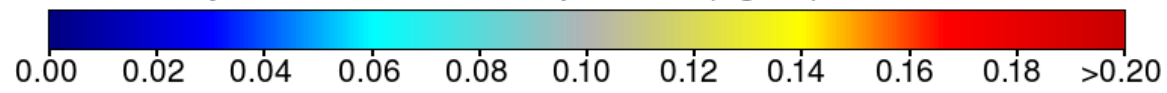


Daily Ammonium Ion Concentration (mg/L): 2014-05-16

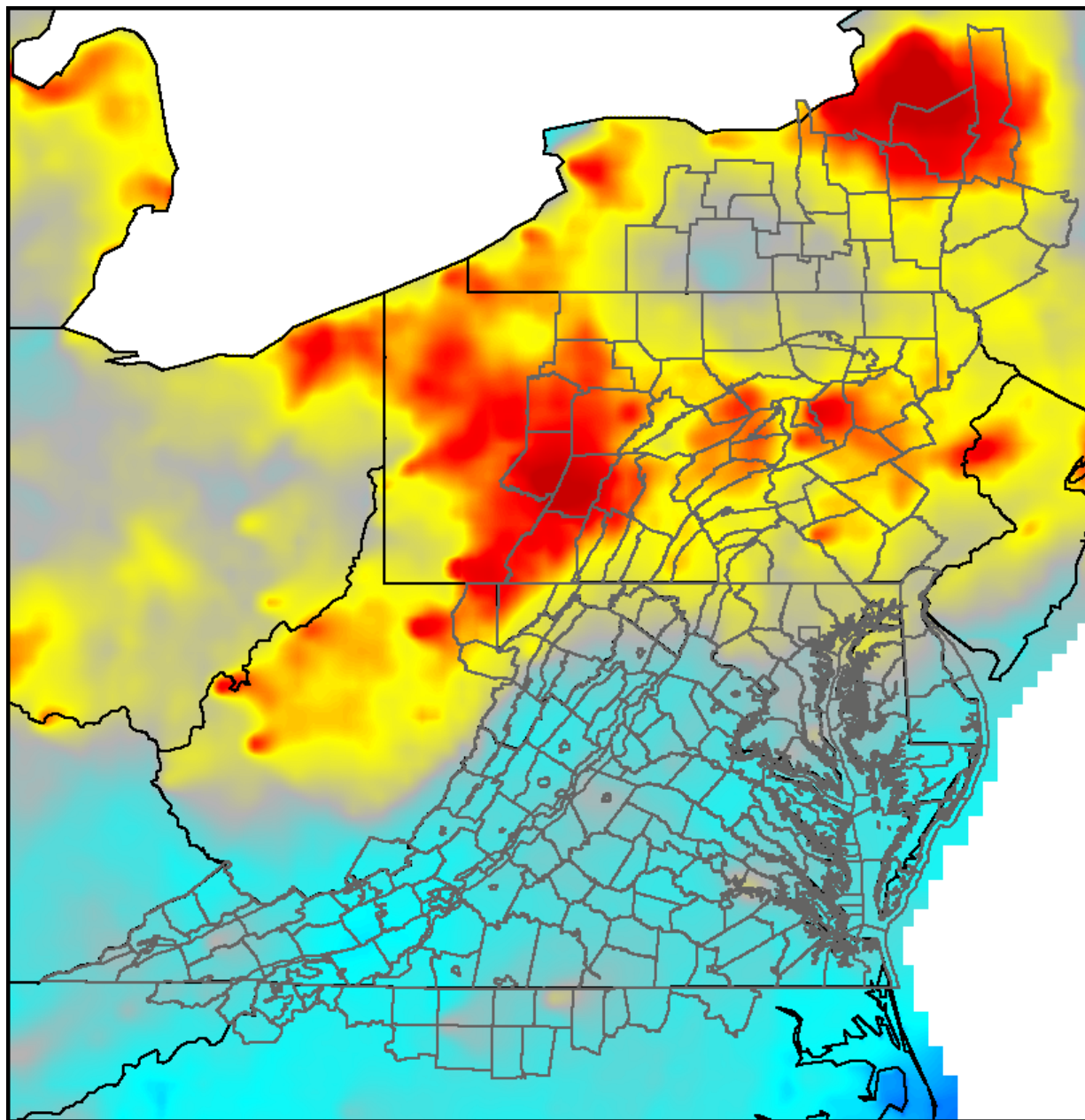




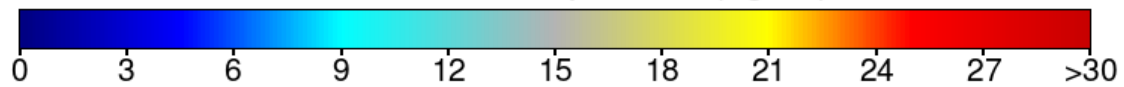
Daily Ammonium Ion Deposition (kg/ha): 2014-05-16

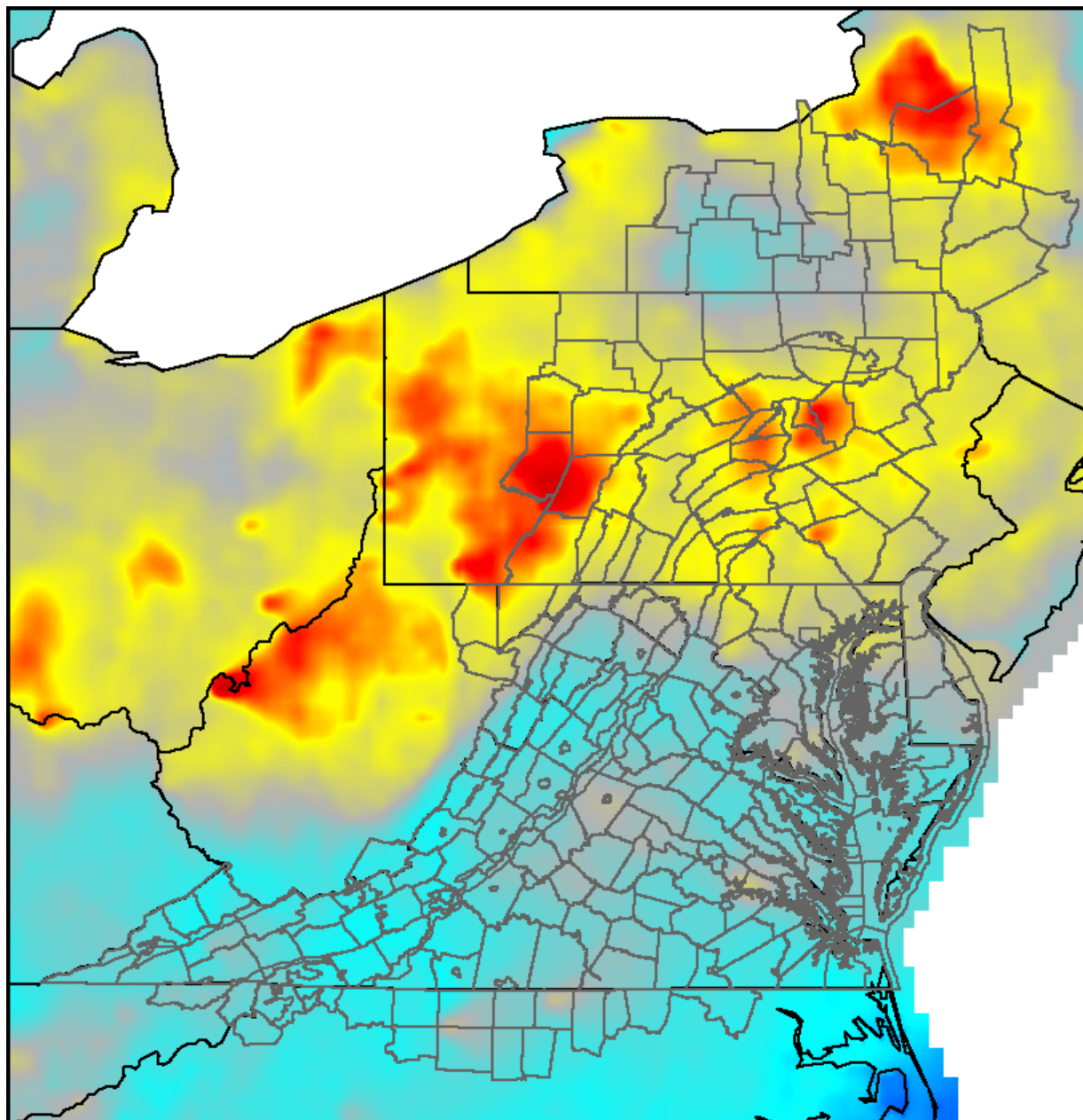




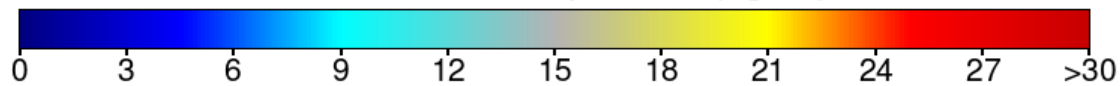


Mean Annual Nitrate Wet Deposition (kg/ha): 1984-1991

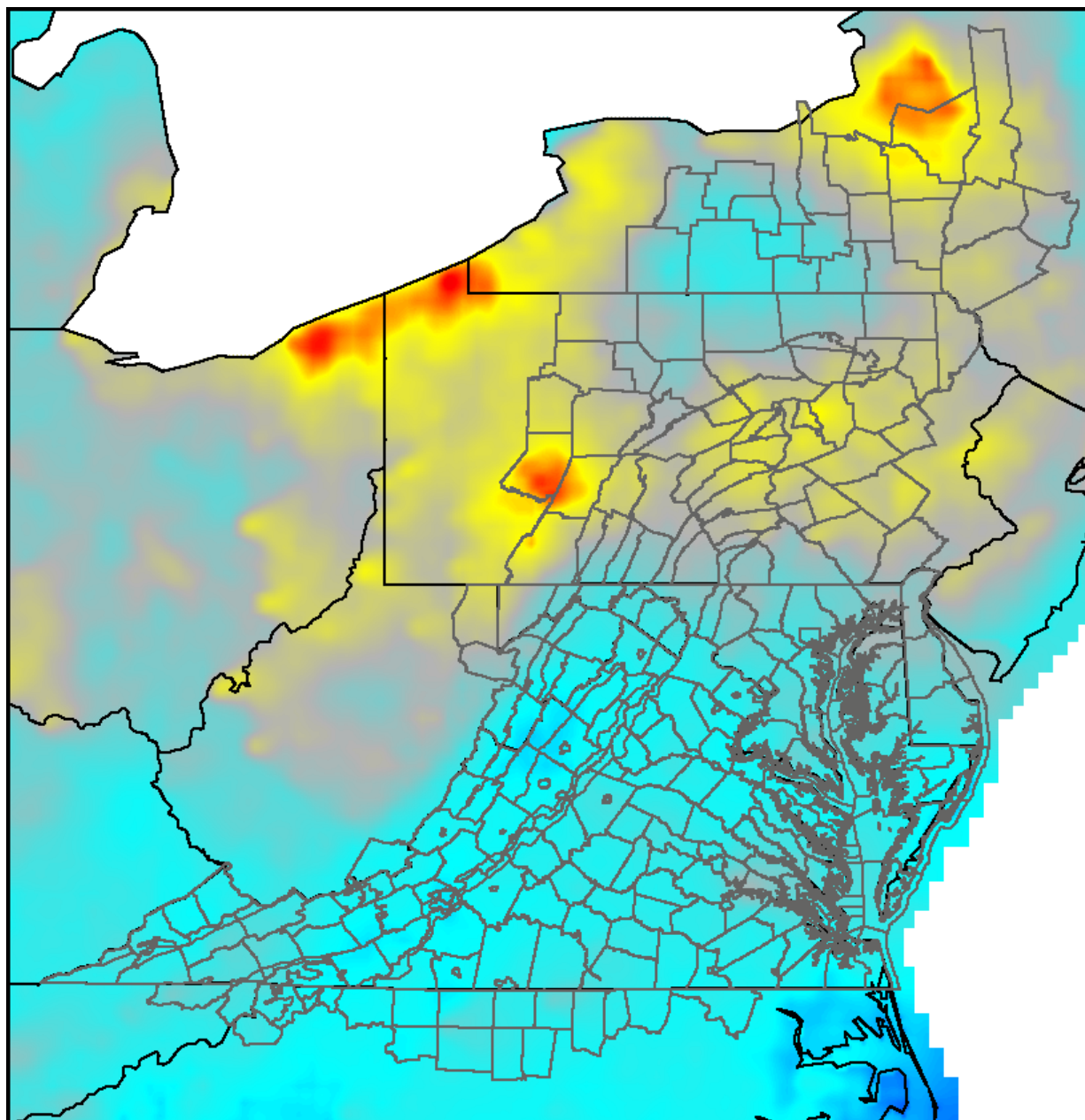




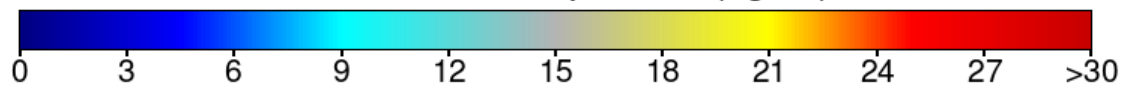
Mean Annual Nitrate Wet Deposition (kg/ha): 1992-1999

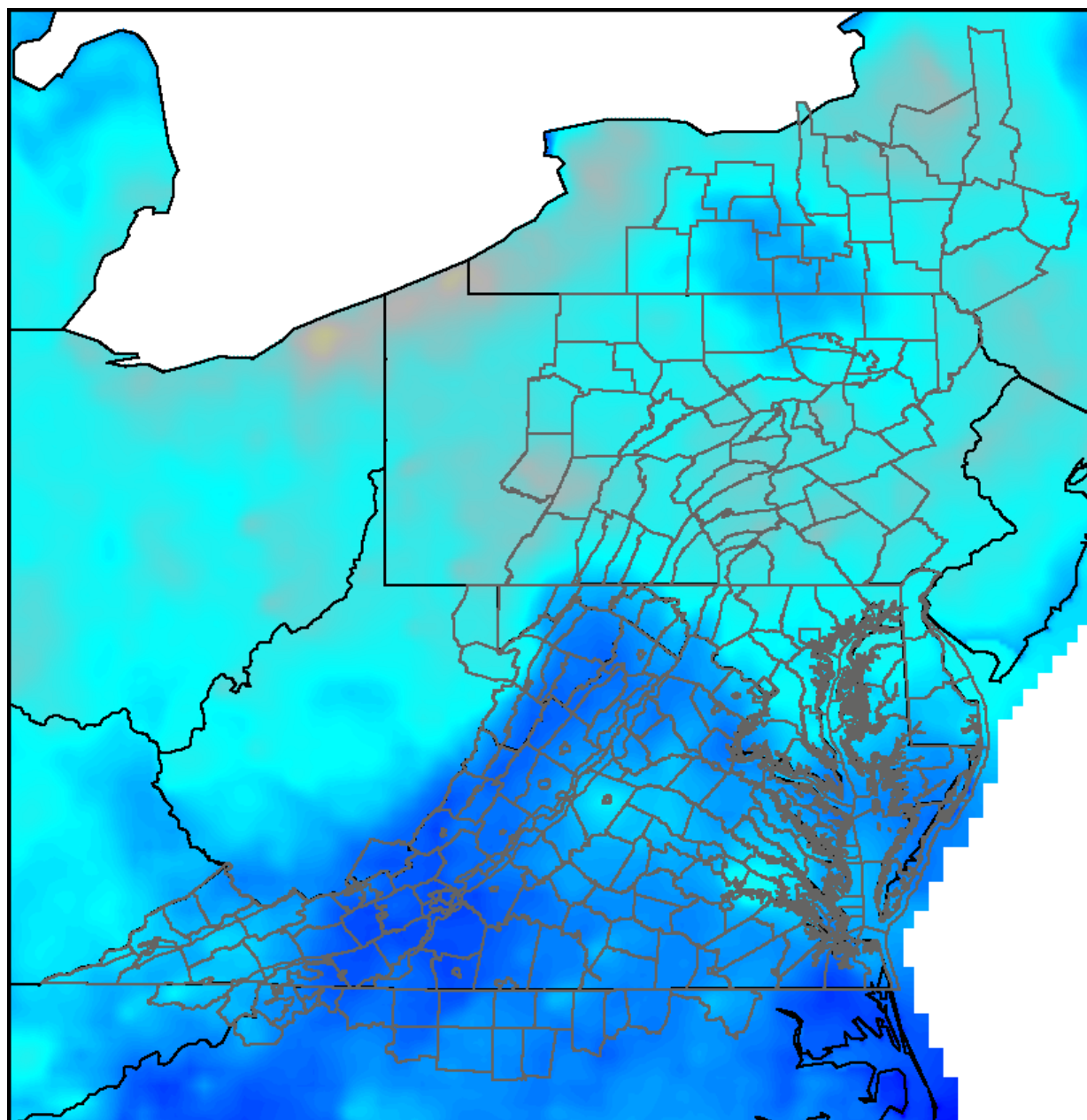




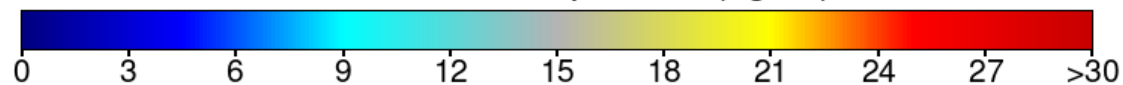


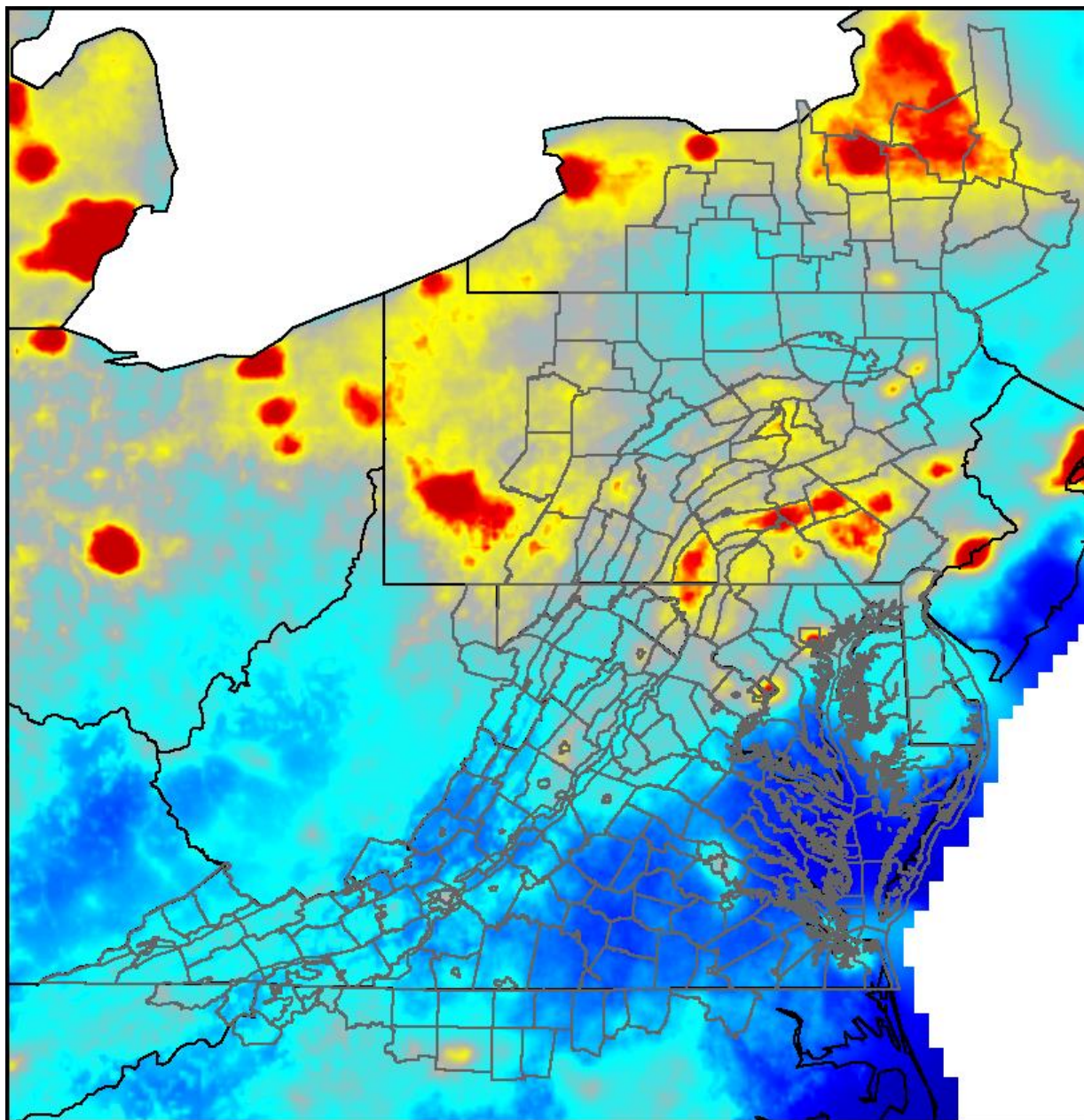
Mean Annual Nitrate Wet Deposition (kg/ha): 2000-2007



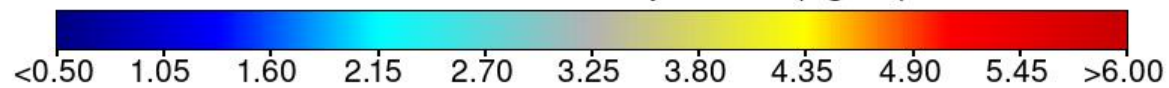


Mean Annual Nitrate Wet Deposition (kg/ha): 2008-2014

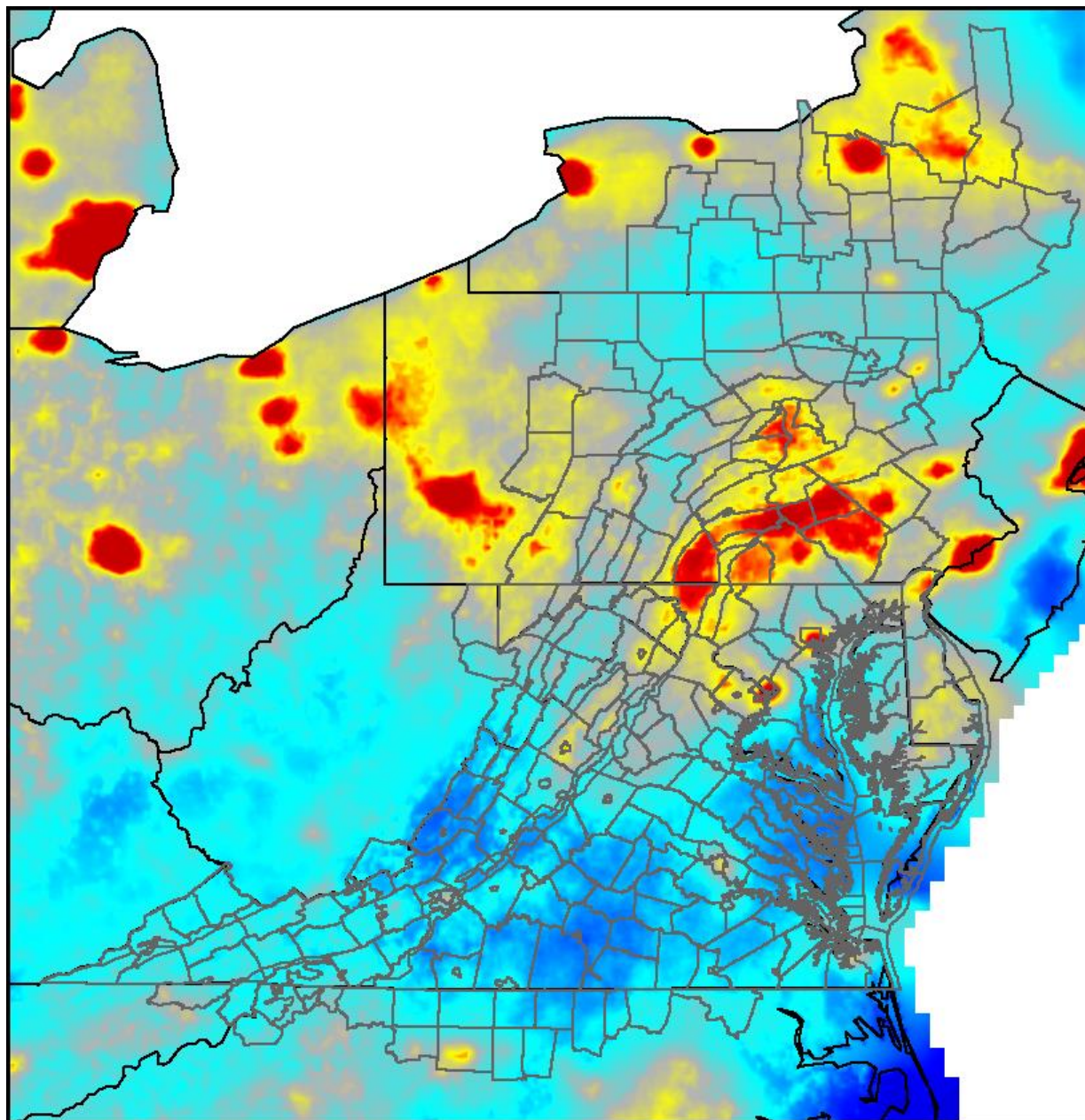




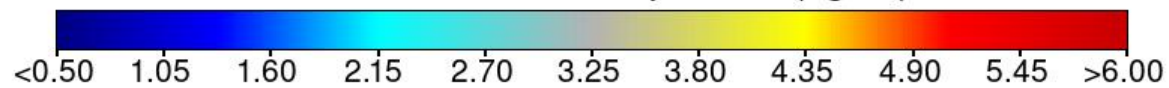
Mean Annual Ammonium Wet Deposition (kg/ha): 1984-1991

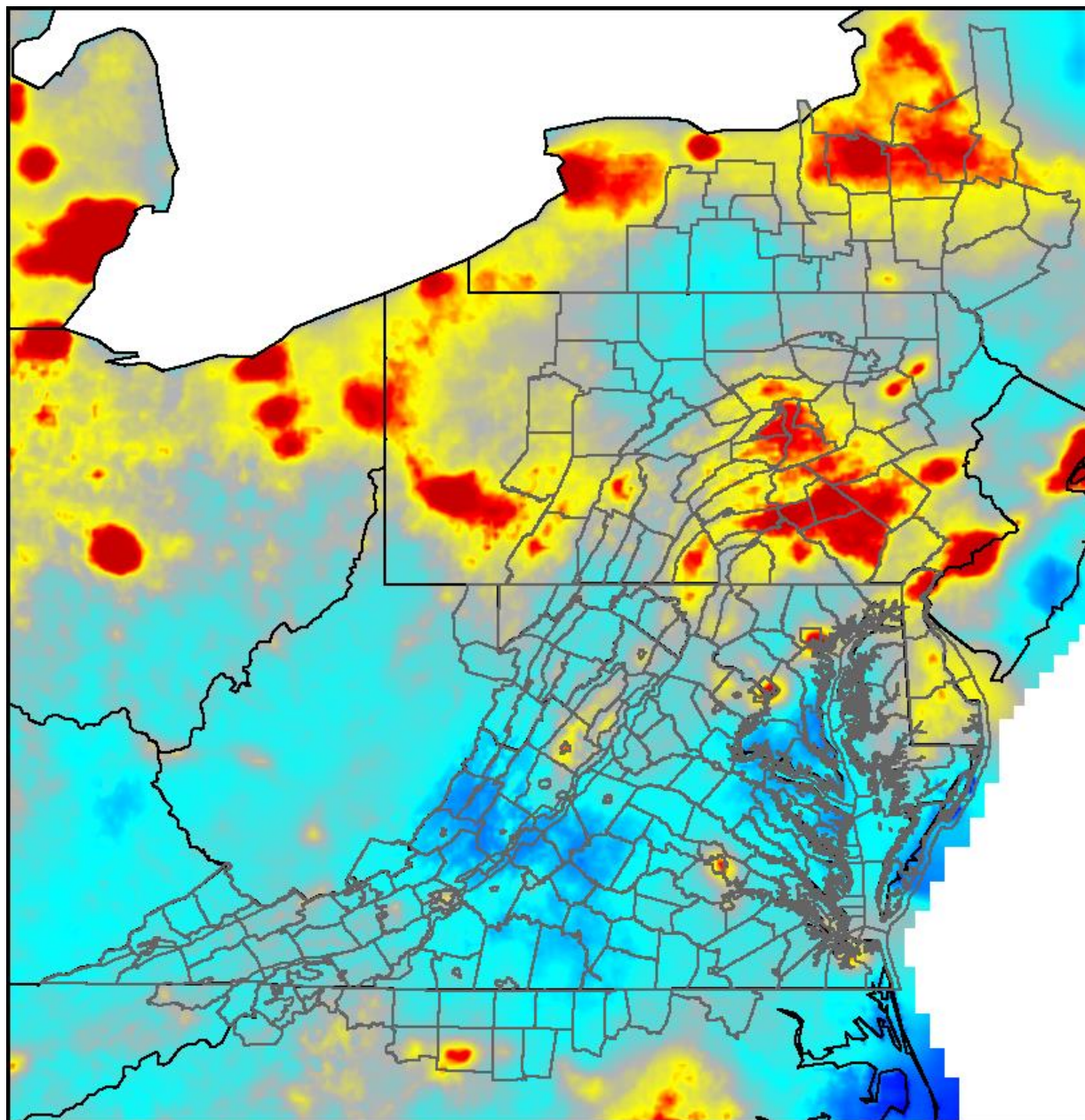




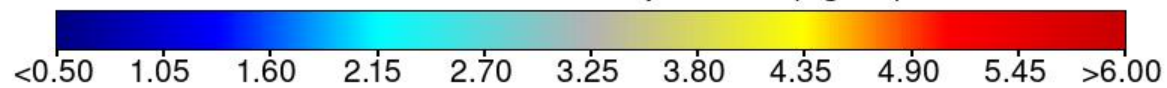


Mean Annual Ammonium Wet Deposition (kg/ha): 1992-1999

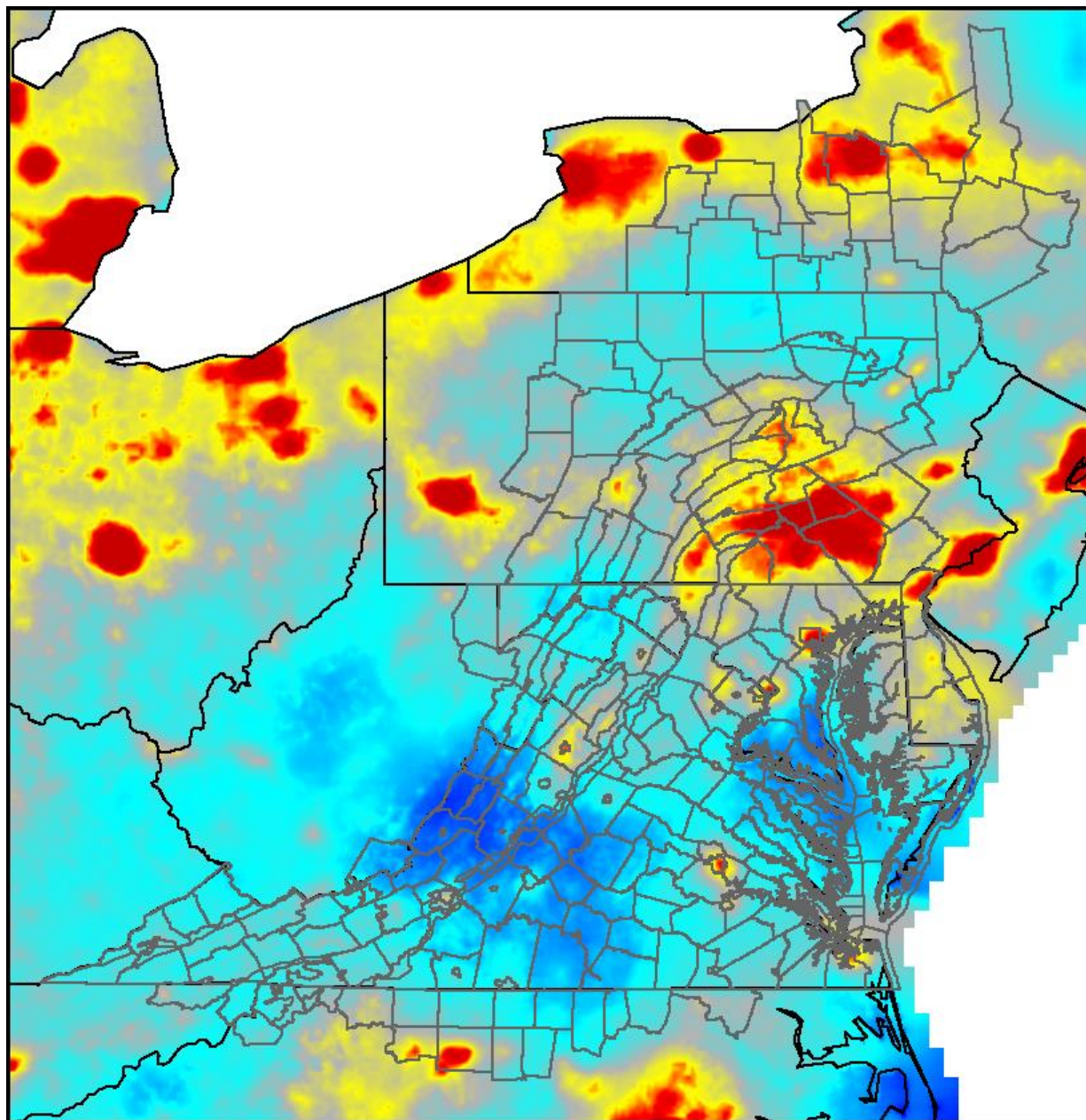




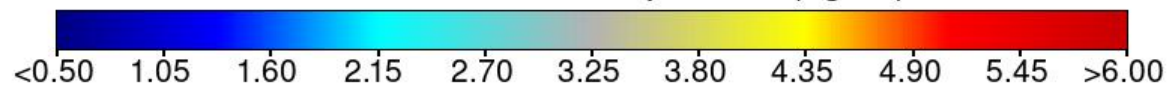
Mean Annual Ammonium Wet Deposition (kg/ha): 2000-2007

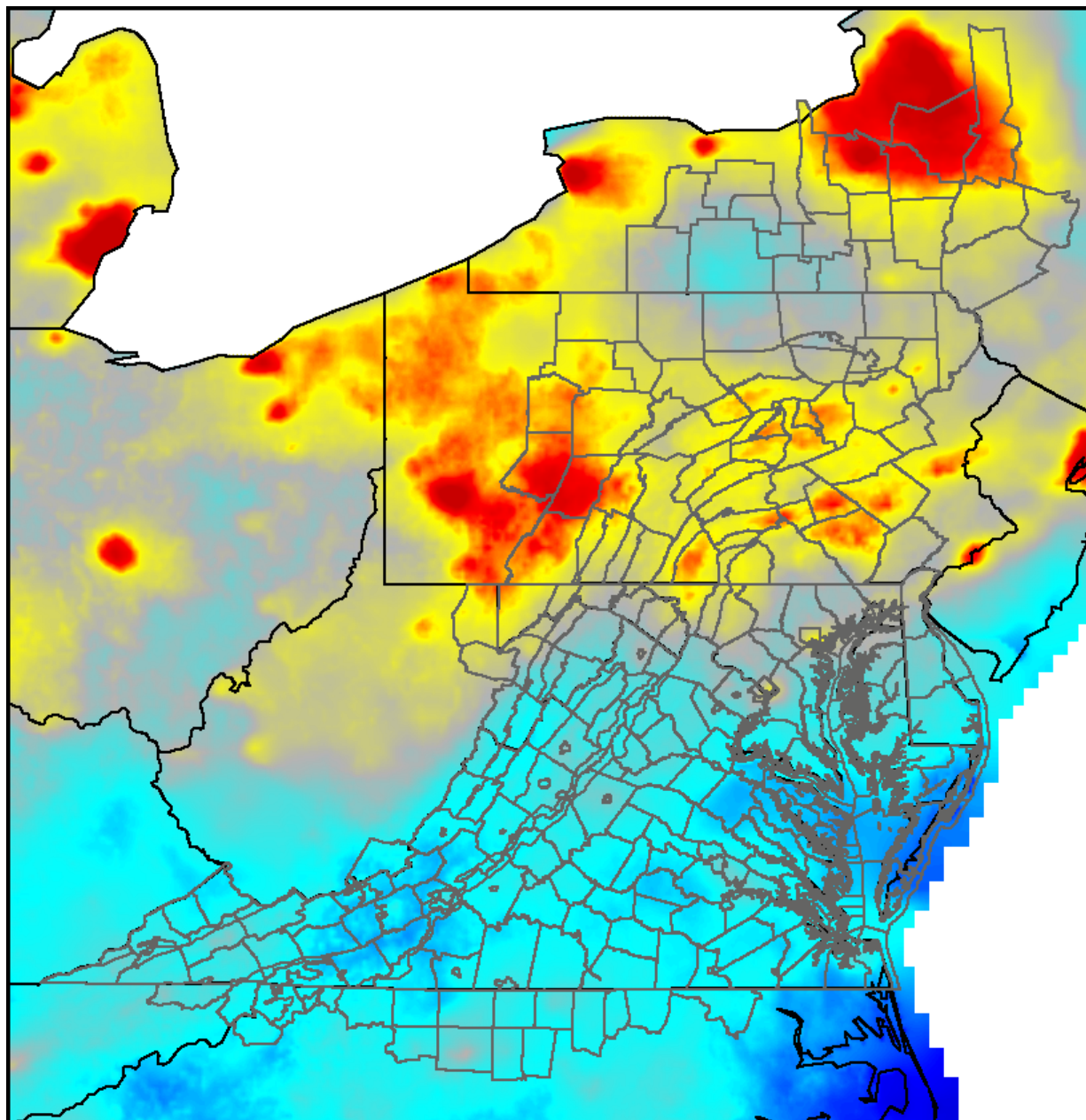




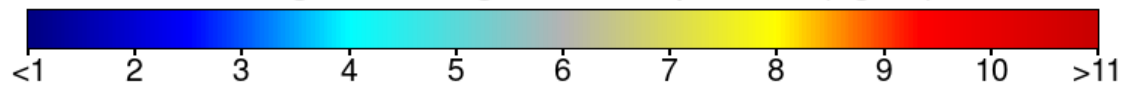


Mean Annual Ammonium Wet Deposition (kg/ha): 2008-2014

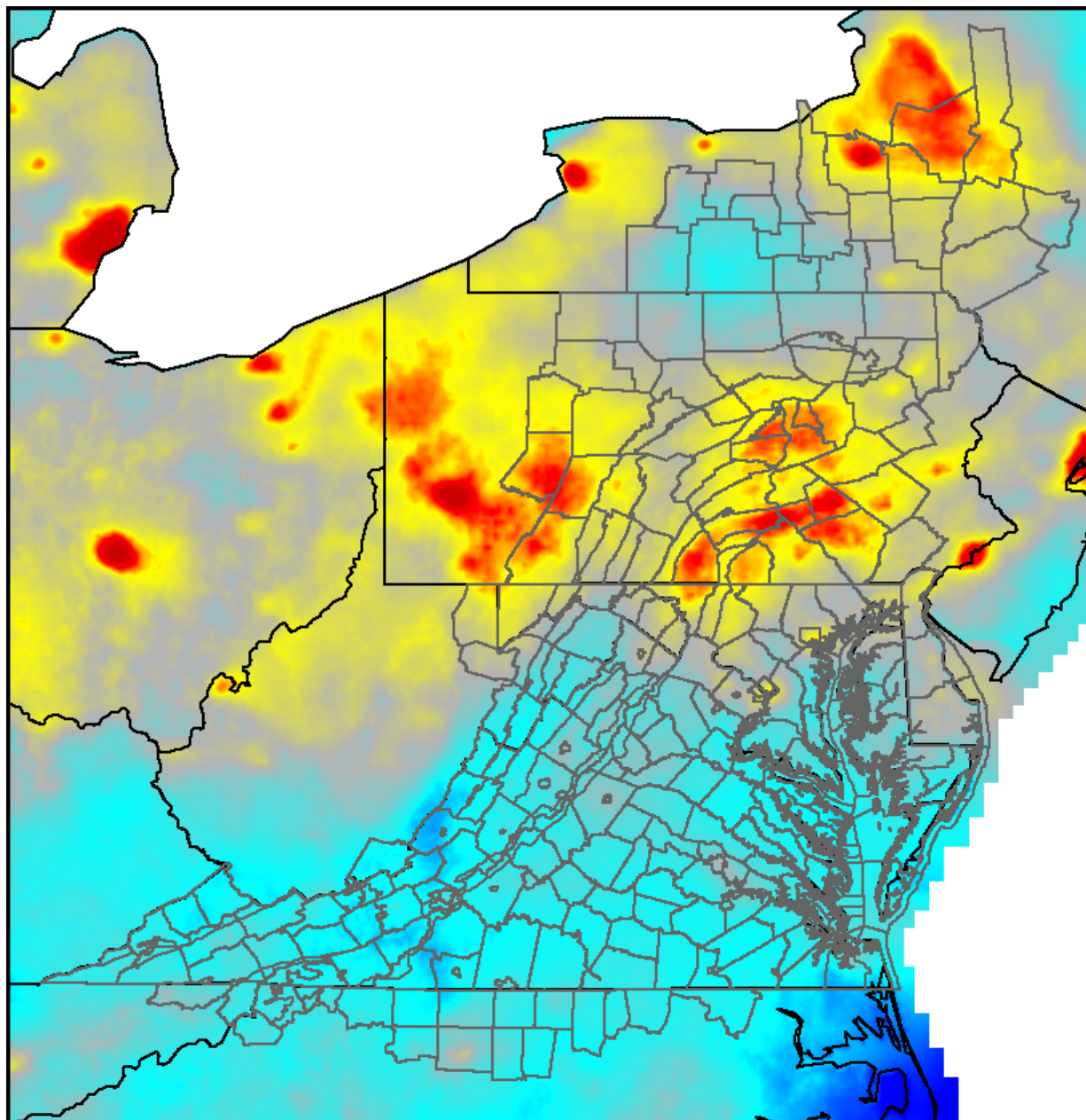




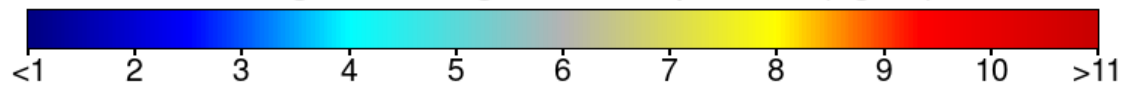
Mean Annual Inorganic Nitrogen Wet Deposition (kg/ha): 1984-1991



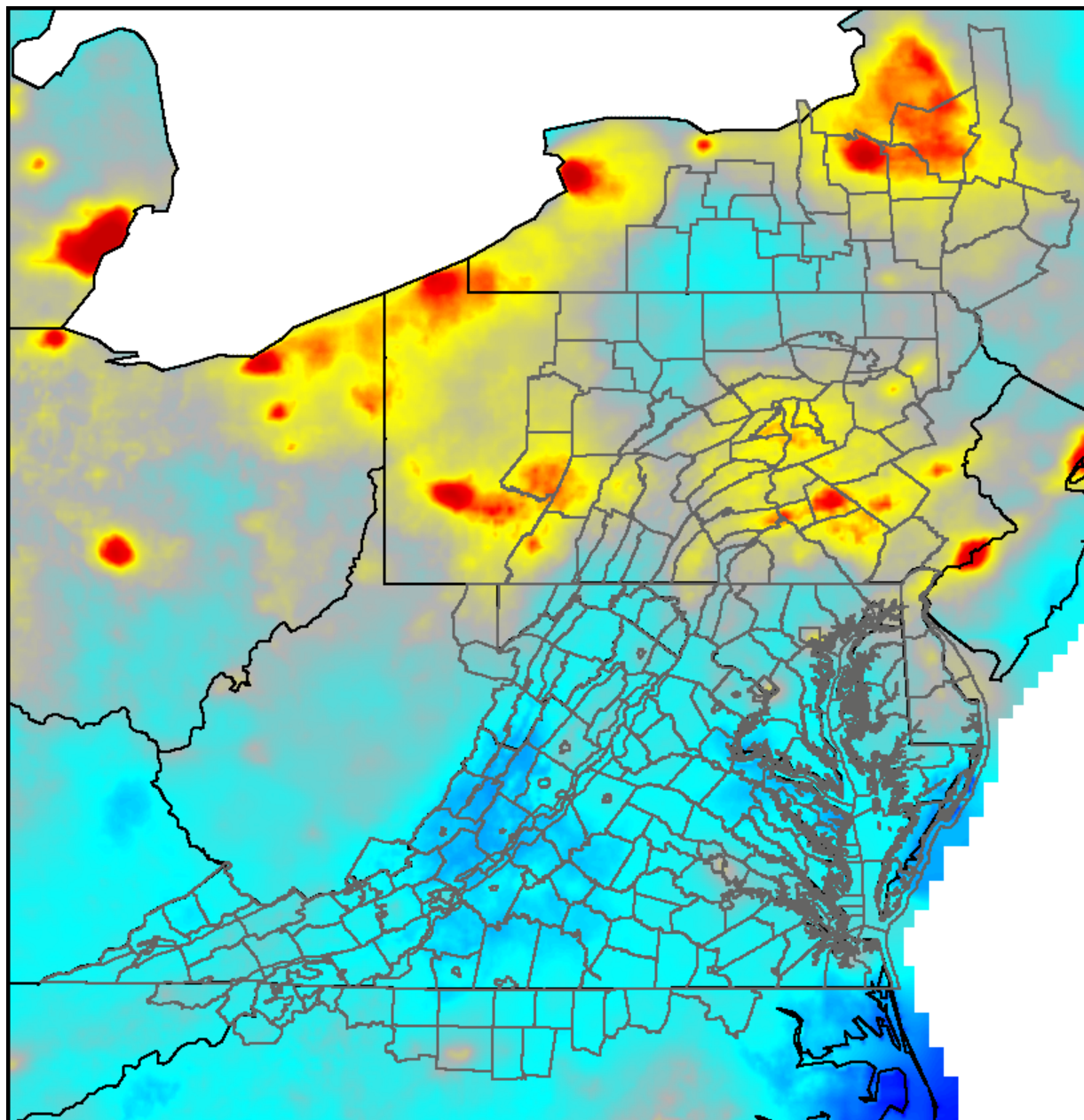




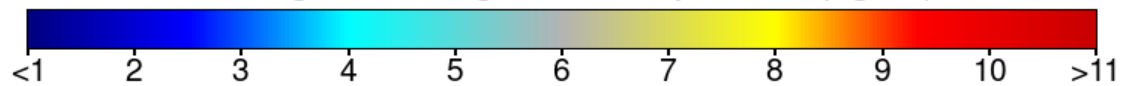
Mean Annual Inorganic Nitrogen Wet Deposition (kg/ha): 1992-1999

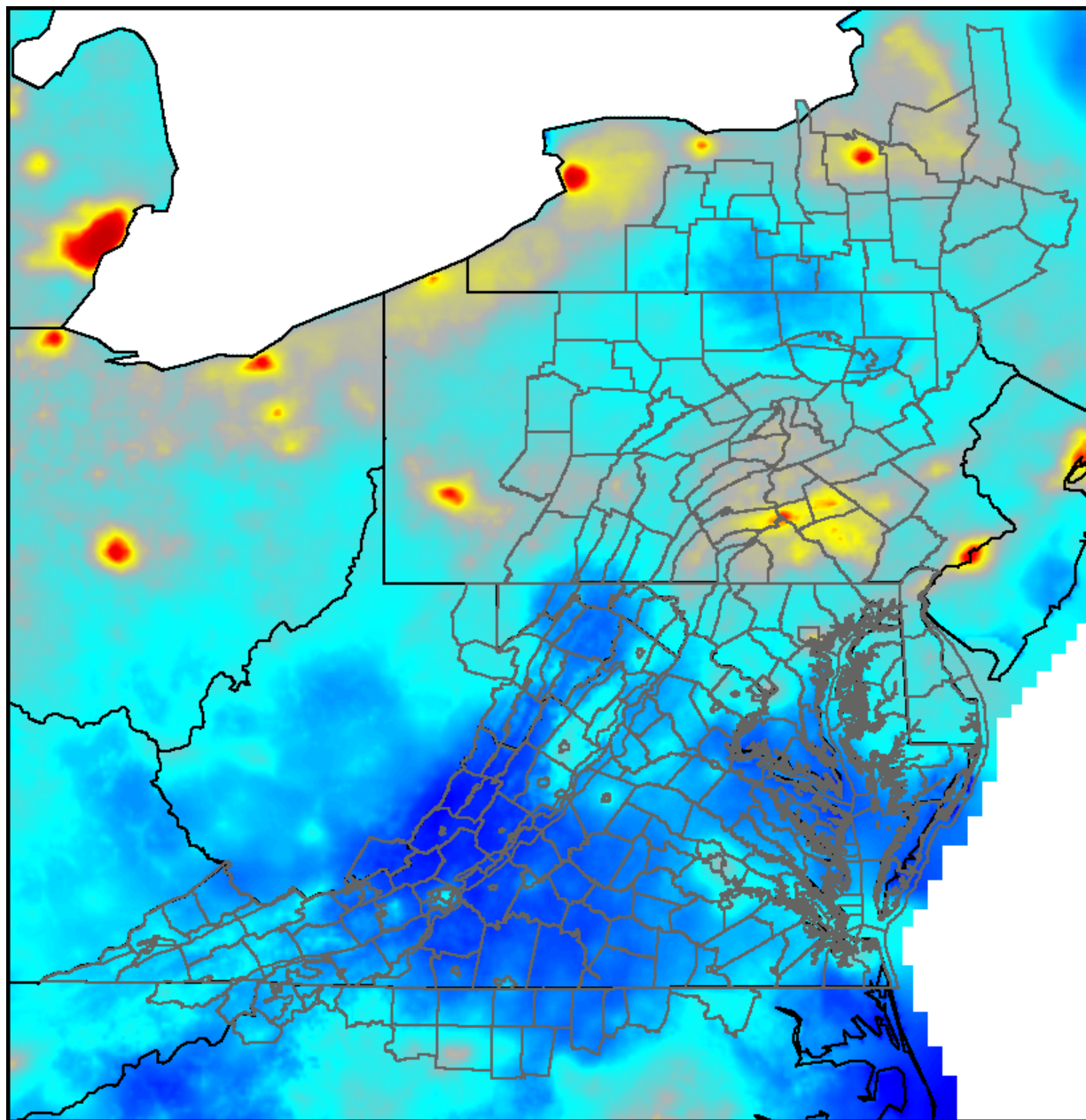




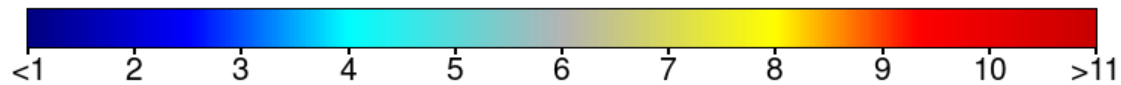


Mean Annual Inorganic Nitrogen Wet Deposition (kg/ha): 2000-2007

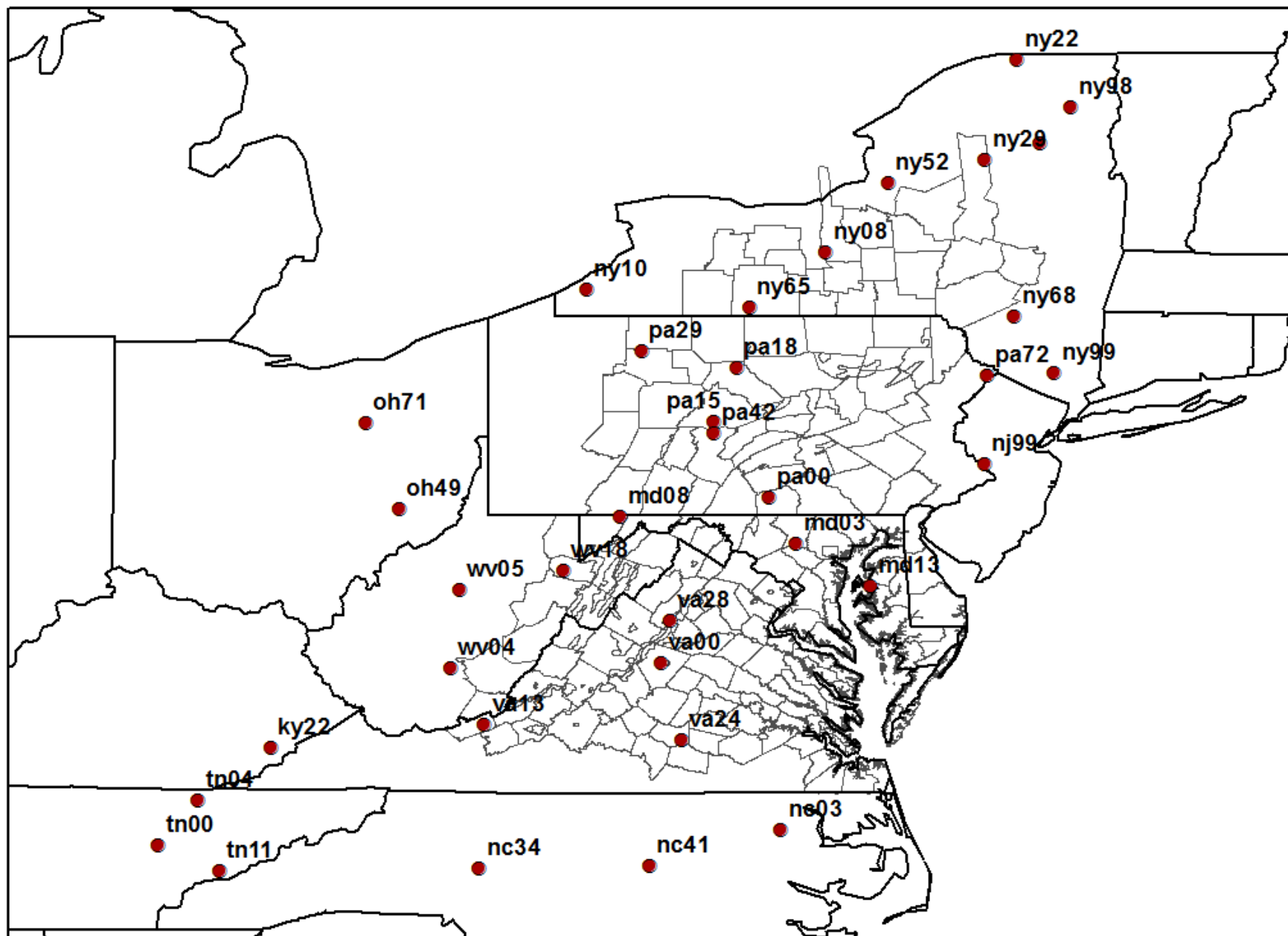




Mean Annual Inorganic Nitrogen Wet Deposition (kg/ha): 2008-2014



## Long-Term NADP Precipitation Chemistry Sites Used for Phase 6 Model Verification



## Model Estimation Errors at Long-Term NTN Sites: Annual Nitrate-N Wet Deposition

Site	# Years	Mean Error (kg N/ha)	Mean Absolute Error (kg N/ha)	Mean % Error	Mean Absolute % Error	Correlation
KY22	31	-0.0081	0.0419	-0.22	1.54	0.9904
MD03	16	-0.0098	0.0469	-0.17	1.28	0.9958
MD08	10	0.0442	0.0492	2.71	2.96	0.9925
MD13	30	0.0067	0.0381	0.26	1.44	0.9967
NC03	31	0.0189	0.0345	0.95	1.57	0.9931
NC34	30	0.0207	0.0478	0.87	1.97	0.9893
NC41	28	0.0048	0.0206	0.24	0.94	0.9978
NJ99	30	0.0699	0.1276	1.96	3.71	0.9818
NY08	31	0.0375	0.0474	1.26	1.56	0.9983
NY10	18	0.0013	0.0873	0.07	1.87	0.9917
NY20	30	-0.0031	0.0437	-0.12	1.41	0.9940
NY22	12	-0.0060	0.0308	-0.22	1.16	0.9981
NY29	11	-0.0055	0.0274	-0.26	1.11	0.9968
NY52	23	0.0593	0.1780	1.23	3.18	0.9811
NY65	17	0.0316	0.0388	1.14	1.39	0.9888
NY68	28	-0.0190	0.0752	-0.50	1.98	0.9891
NY98	27	-0.0219	0.0492	-0.71	1.74	0.9941
NY99	28	0.0318	0.0992	0.82	2.37	0.9877
OH49	30	0.0044	0.0345	0.17	1.01	0.9984
OH71	31	0.0007	0.0339	0.01	1.12	0.9974
PA00	15	0.0044	0.0589	0.33	2.04	0.9921
PA15	30	0.0312	0.0687	0.87	2.39	0.9958
PA18	14	0.0156	0.0425	0.51	1.49	0.9971
PA29	48	0.0110	0.0545	0.40	1.34	0.9982
PA42	30	0.0147	0.0501	0.42	1.38	0.9979
PA72	24	0.0243	0.0977	0.69	2.61	0.9850
TN00	25	-0.0082	0.0262	-0.19	0.85	0.9979
TN04	15	-0.0191	0.0311	-0.74	1.40	0.9914
TN11	29	-0.0058	0.0499	-0.17	1.84	0.9915
VA00	24	-0.0716	0.0888	-2.28	2.88	0.9754
VA13	23	0.0055	0.0279	0.28	1.37	0.9973
VA24	15	-0.0331	0.0813	-0.56	3.10	0.9671
VA28	21	0.0102	0.0343	0.28	1.49	0.9962
WV04	19	0.0064	0.0515	0.23	1.59	0.9900
WV05	14	0.0336	0.0535	1.06	1.85	0.9955
WV18	30	-0.0307	0.0582	-0.69	1.41	0.9940

## Model Estimation Errors at Long-Term NTN Sites: Annual Ammonium-N Wet Deposition

Site	# Years	Mean Error (kg N/ha)	Mean Absolute Error (kg N/ha)	Mean % Error	Mean Absolute % Error	Correlation
KY22	31	0.0018	0.0302	0.37	2.02	0.9941
MD03	16	0.0014	0.0457	0.15	2.12	0.9910
MD08	10	0.0556	0.0556	4.33	4.33	0.9895
MD13	30	-0.0089	0.0304	-0.36	1.52	0.9914
NC03	31	0.0114	0.0316	0.91	1.97	0.9961
NC34	30	0.0412	0.0642	1.95	2.90	0.9913
NC41	28	0.0224	0.0338	0.76	1.36	0.9983
NJ99	30	0.0365	0.0927	1.93	4.43	0.9632
NY08	31	0.0013	0.0435	0.19	1.63	0.9924
NY10	18	0.0195	0.0553	0.73	1.91	0.9926
NY20	30	-0.0223	0.0417	-1.41	2.50	0.9769
NY22	12	-0.0022	0.0365	-0.15	1.62	0.9867
NY29	11	0.0207	0.0301	1.03	1.60	0.9943
NY52	23	0.0132	0.0974	0.49	2.69	0.9745
NY65	17	0.0071	0.0260	0.67	1.74	0.9946
NY68	28	-0.0171	0.0703	-0.59	3.21	0.9603
NY98	27	-0.0100	0.0473	-0.27	2.44	0.9799
NY99	28	0.0504	0.0810	2.29	3.71	0.9824
OH49	30	0.0036	0.0545	0.23	2.42	0.9863
OH71	31	0.0082	0.0346	0.39	1.26	0.9970
PA00	15	0.0221	0.0826	1.09	2.71	0.9842
PA15	30	0.0467	0.0745	2.38	3.84	0.9686
PA18	14	0.0023	0.0550	0.56	2.61	0.9919
PA29	48	-0.0275	0.0766	-1.01	3.01	0.9763
PA42	30	0.0261	0.0562	1.24	2.51	0.9861
PA72	24	0.0374	0.0785	1.39	3.72	0.9765
TN00	25	0.0154	0.0327	1.02	1.81	0.9977
TN04	15	-0.0156	0.0292	-0.69	1.47	0.9958
TN11	29	-0.0379	0.0577	-1.70	2.80	0.9845
VA00	24	-0.0120	0.0613	-0.45	3.28	0.9631
VA13	23	-0.0024	0.0251	-0.01	1.65	0.9967
VA24	15	-0.0291	0.0738	-0.92	3.66	0.9423
VA28	21	-0.0306	0.0529	-1.37	2.37	0.9814
WV04	19	-0.0134	0.0440	-0.69	2.41	0.9904
WV05	14	0.0336	0.0515	1.69	2.73	0.9811
WV18	30	-0.0116	0.0411	-0.45	1.78	0.9864

## Model Estimation Errors at Long-Term NTN Sites: Annual Inorganic Nitrogen Wet Deposition

Site	# Years	Mean Error (kg N/ha)	Mean Absolute Error (kg N/ha)	Mean % Error	Mean Absolute % Error	Correlation
KY22	31	-0.0064	0.0697	-0.01	1.65	0.9889
MD03	16	-0.0085	0.0894	-0.05	1.51	0.9943
MD08	10	0.0998	0.0998	3.34	3.34	0.9901
MD13	30	-0.0022	0.0599	-0.01	1.27	0.9947
NC03	31	0.0302	0.0617	0.84	1.58	0.9880
NC34	30	0.0620	0.1078	1.46	2.43	0.9853
NC41	28	0.0272	0.0478	0.58	1.03	0.9974
NJ99	30	0.1064	0.2174	1.90	3.95	0.9698
NY08	31	0.0388	0.0809	0.70	1.43	0.9948
NY10	18	0.0208	0.1279	0.29	1.65	0.9916
NY20	30	-0.0254	0.0764	-0.64	1.61	0.9897
NY22	12	-0.0083	0.0583	-0.25	1.21	0.9967
NY29	11	0.0152	0.0503	0.27	1.14	0.9963
NY52	23	0.0725	0.2685	0.91	2.92	0.9784
NY65	17	0.0387	0.0621	0.92	1.42	0.9922
NY68	28	-0.0360	0.1410	-0.50	2.37	0.9716
NY98	27	-0.0319	0.0895	-0.55	1.84	0.9881
NY99	28	0.0822	0.1724	1.34	2.78	0.9841
OH49	30	0.0080	0.0781	0.18	1.36	0.9956
OH71	31	0.0089	0.0619	0.18	1.08	0.9956
PA00	15	0.0265	0.1333	0.75	2.26	0.9858
PA15	30	0.0779	0.1416	1.49	2.93	0.9872
PA18	14	0.0178	0.0953	0.48	1.91	0.9925
PA29	48	-0.0165	0.1284	-0.15	1.93	0.9945
PA42	30	0.0407	0.1018	0.70	1.68	0.9957
PA72	24	0.0616	0.1744	1.01	3.01	0.9700
TN00	25	0.0072	0.0539	0.28	1.09	0.9977
TN04	15	-0.0347	0.0548	-0.74	1.32	0.9866
TN11	29	-0.0437	0.1016	-0.76	2.14	0.9891
VA00	24	-0.0836	0.1471	-1.53	2.96	0.9613
VA13	23	0.0030	0.0513	0.13	1.47	0.9962
VA24	15	-0.0621	0.1525	-0.75	3.28	0.9588
VA28	21	-0.0204	0.0815	-0.58	1.89	0.9898
WV04	19	-0.0070	0.0821	-0.10	1.59	0.9901
WV05	14	0.0673	0.1028	1.31	2.16	0.9919
WV18	30	-0.0423	0.0912	-0.59	1.36	0.9903

Short-range extrapolation models for ammonium-N, nitrate-N, and total inorganic N annual wet deposition for each Phase 6 Land Segment or Water Quality Model cell have the following form:

$$\log_{10}(N_{\text{dep}}) = b_0 + b_1 \cdot \text{year}_{\text{adj}} + b_2 \cdot \sqrt{\text{year}_{\text{adj}}}$$

or

$$N_{\text{dep}} = 10.0 ^ { [b_0 + b_1 \cdot \text{year}_{\text{adj}} + b_2 \cdot \sqrt{\text{year}_{\text{adj}}}] }$$

Where,

$N_{\text{dep}}$  = estimated annual wet deposition of nitrogen in lb/acre for land segments and kg/ha for water quality model cells

$\text{year}_{\text{base}}$  = Year baseline model parameter (e.g., 1978)

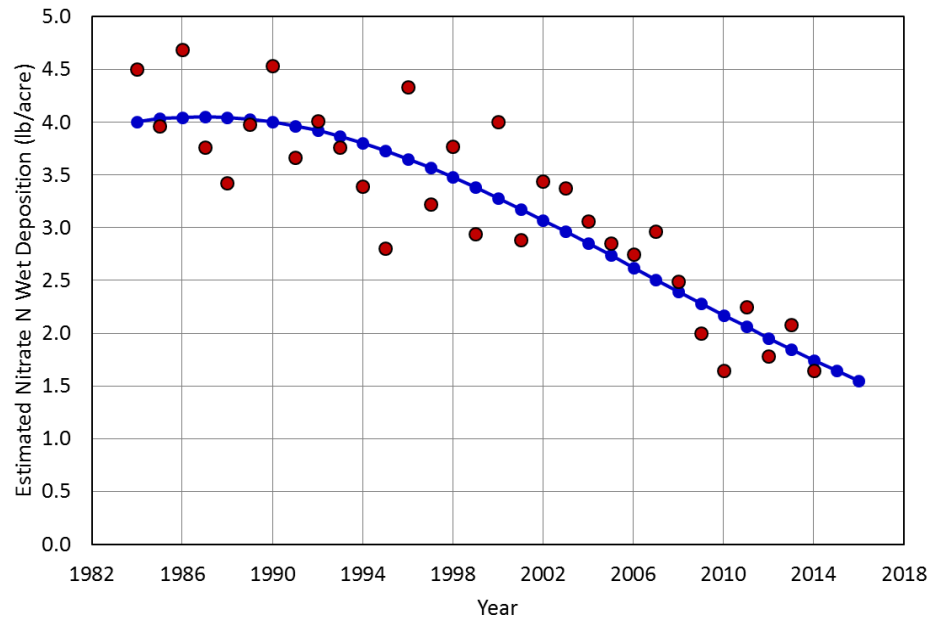
$\text{year}_{\text{adj}}$  = Year to be estimated -  $\text{year}_{\text{base}}$  model parameter (e.g., 2016 – 1978 = 38)

$b_0$  = model intercept parameter

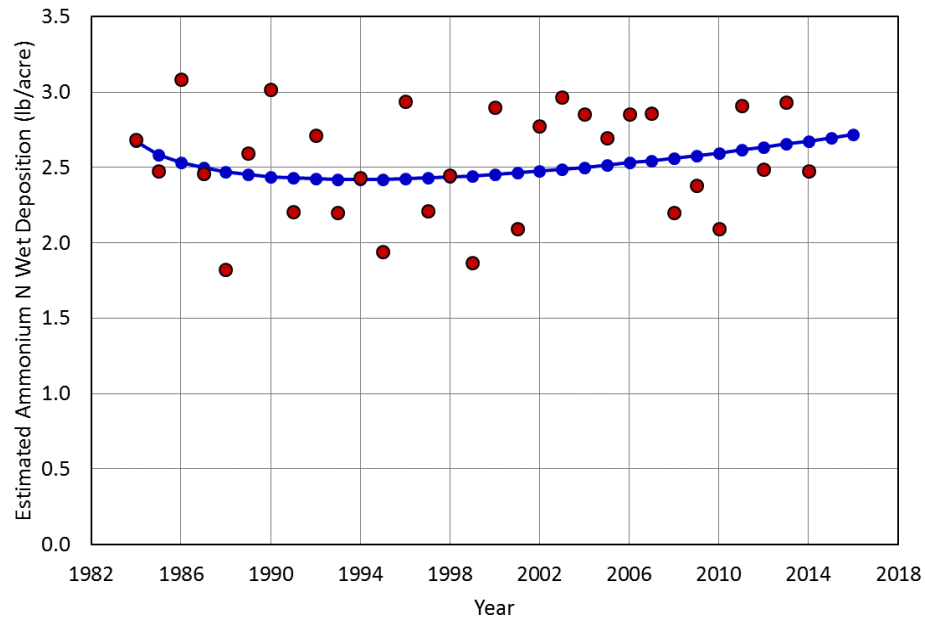
$b_1$  = slope parameter for the  $\text{year}_{\text{adj}}$  model predictor

$b_2$  = slope parameter for the  $\sqrt{\text{year}_{\text{adj}}}$  model predictor

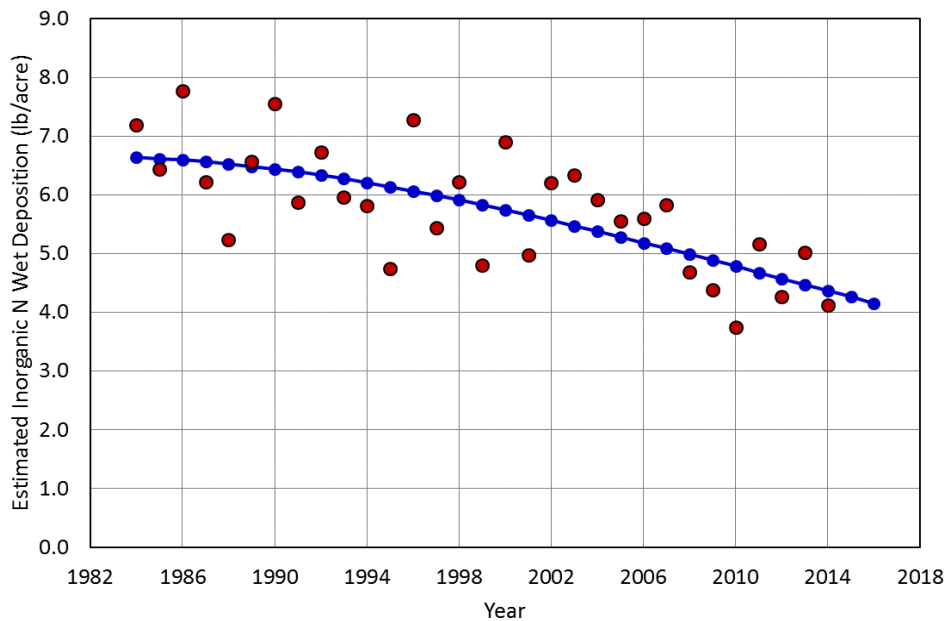
**Annual Nitrate N Wet Deposition Estimates for Cortland County, NY (N36023)**



**Annual Ammonium N Wet Deposition Estimates for Cortland County, NY (N36023)**

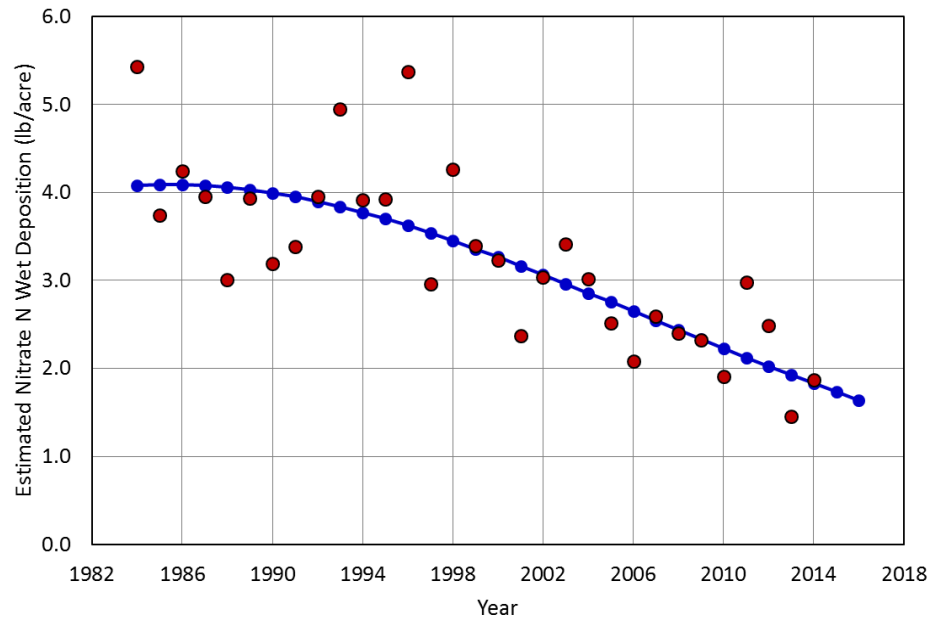


**Annual Inorganic N Wet Deposition Estimates for Cortland County, NY (N36023)**

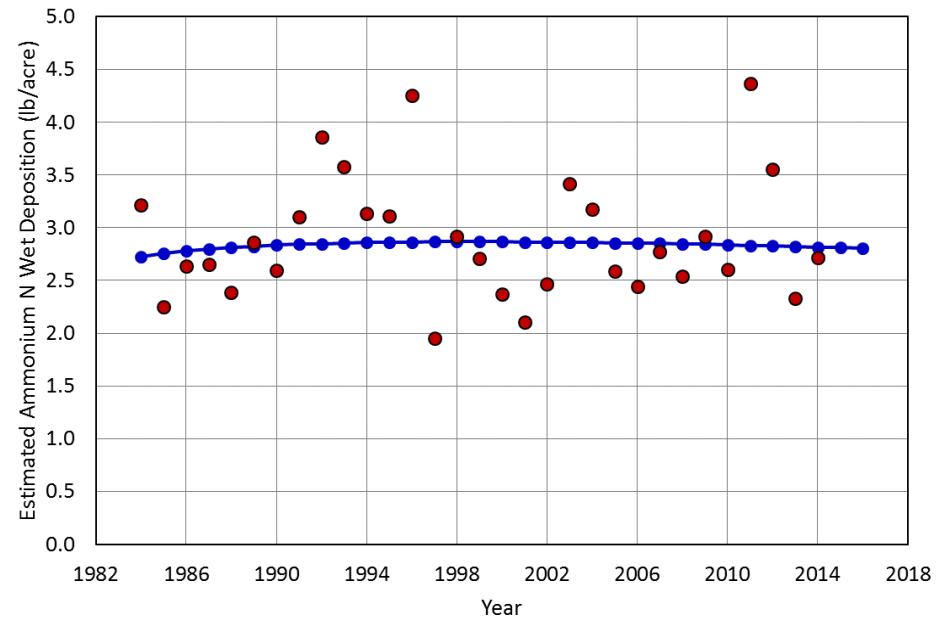




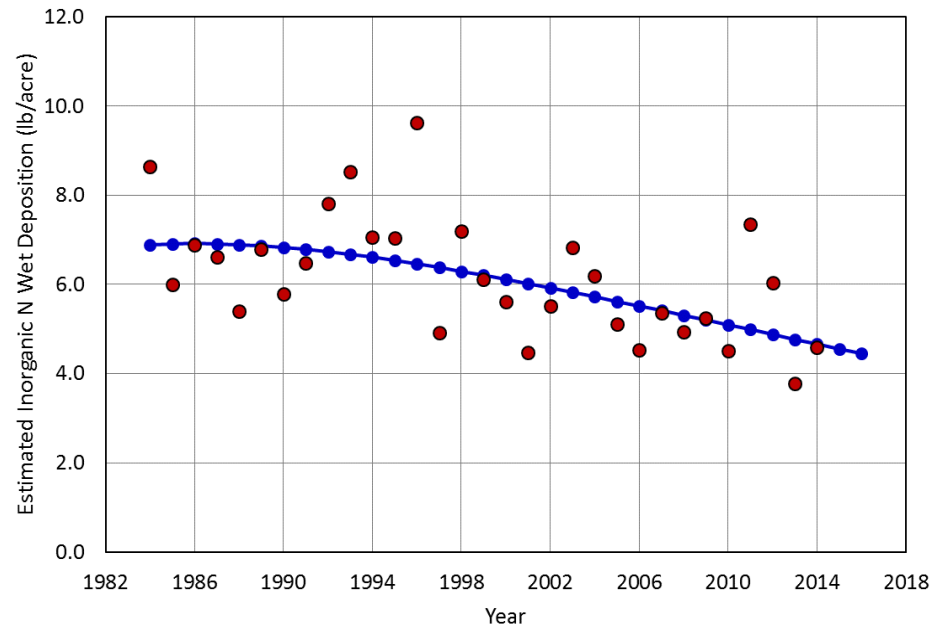
**Annual Nitrate N Wet Deposition Estimates for Adams County, PA (N42001)**



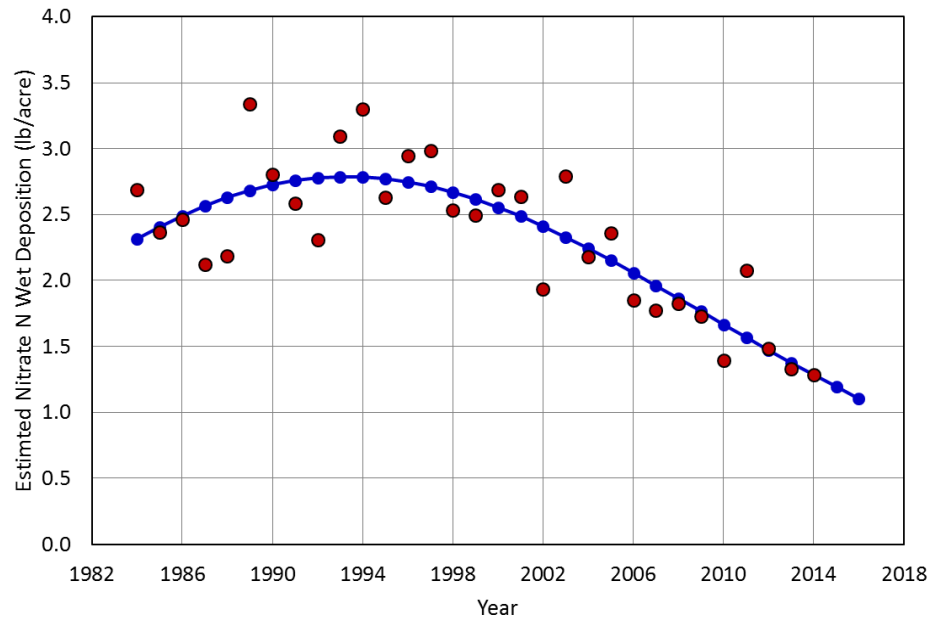
**Annual Ammonium N Wet Deposition Estimates for Adams County, PA (N42001)**



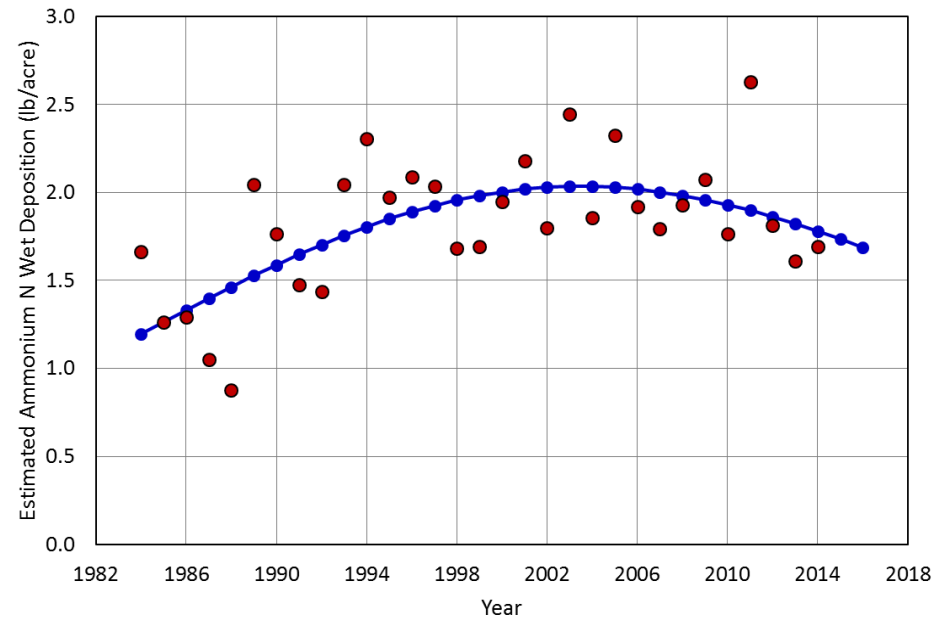
**Annual Inorganic N Wet Deposition Estimates for Adams County, PA (N42001)**



**Annual Nitrate N Wet Deposition Estimates for Dorchester County, MD (N24019)**



**Annual Ammonium N Wet Deposition Estimates for Dorchester County, MD (N24019)**



**Annual Inorganic N Wet Deposition Estimates for Dorchester County, MD (N24019)**

