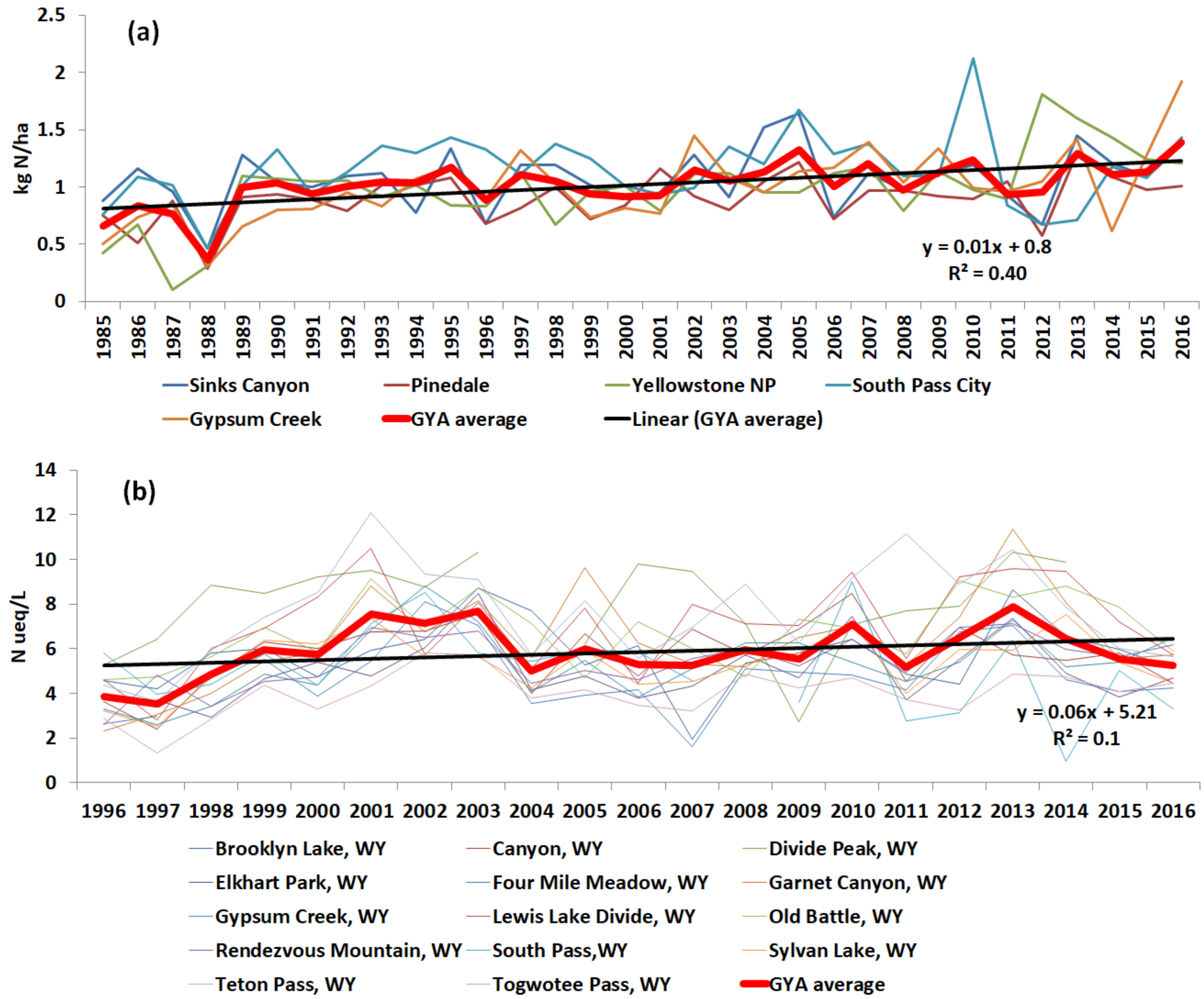

Figure S1. (a) Annual trend of measured wet N_r deposition measured at National Trend Network (NTN) sites (the Grand Teton site (WY94) was excluded into trend analysis since it start to operate in 2011), (b) mean total N concentration (NH4+NO3) in snow pack measured at Rocky Mountain Regional snow pack Chemistry (RMRSC) network sites within the GYA

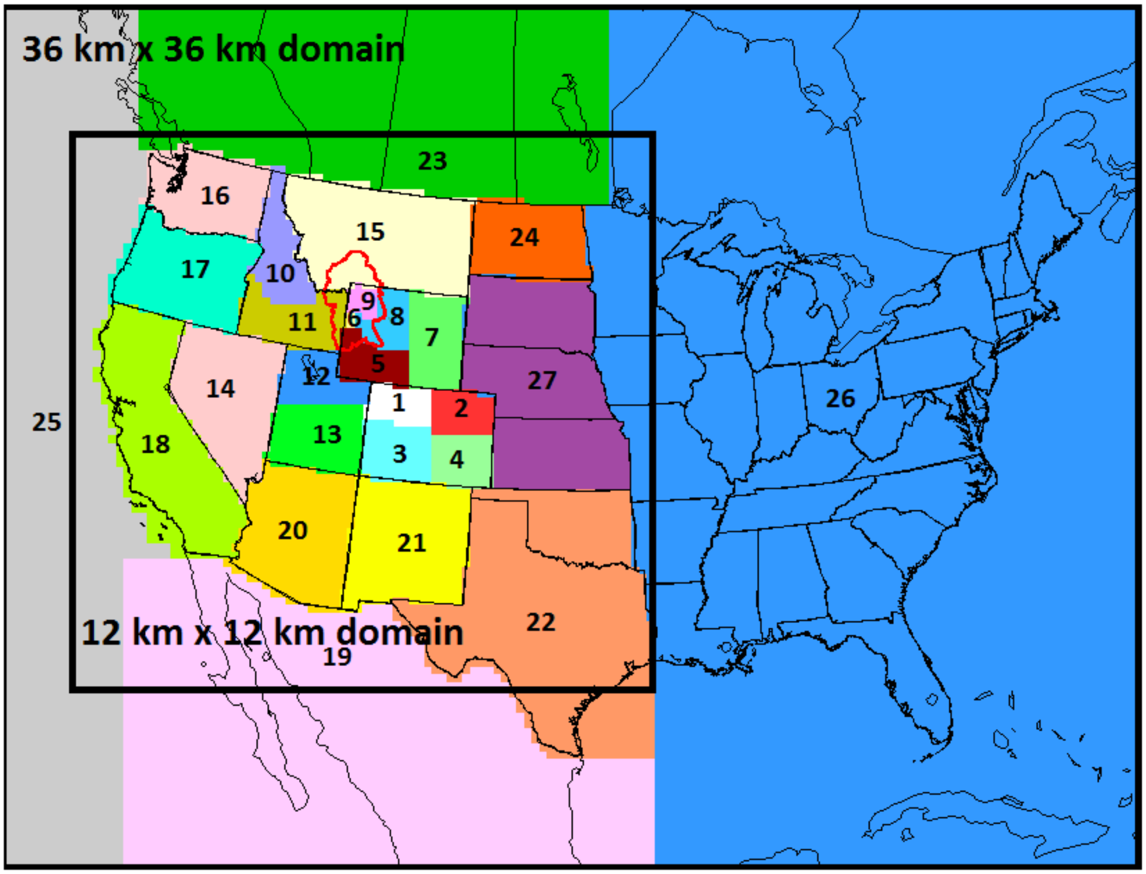

Figure S2. Source region partition for CAMx PSAT simulation in this study (also see Table 2 for detail region definition).

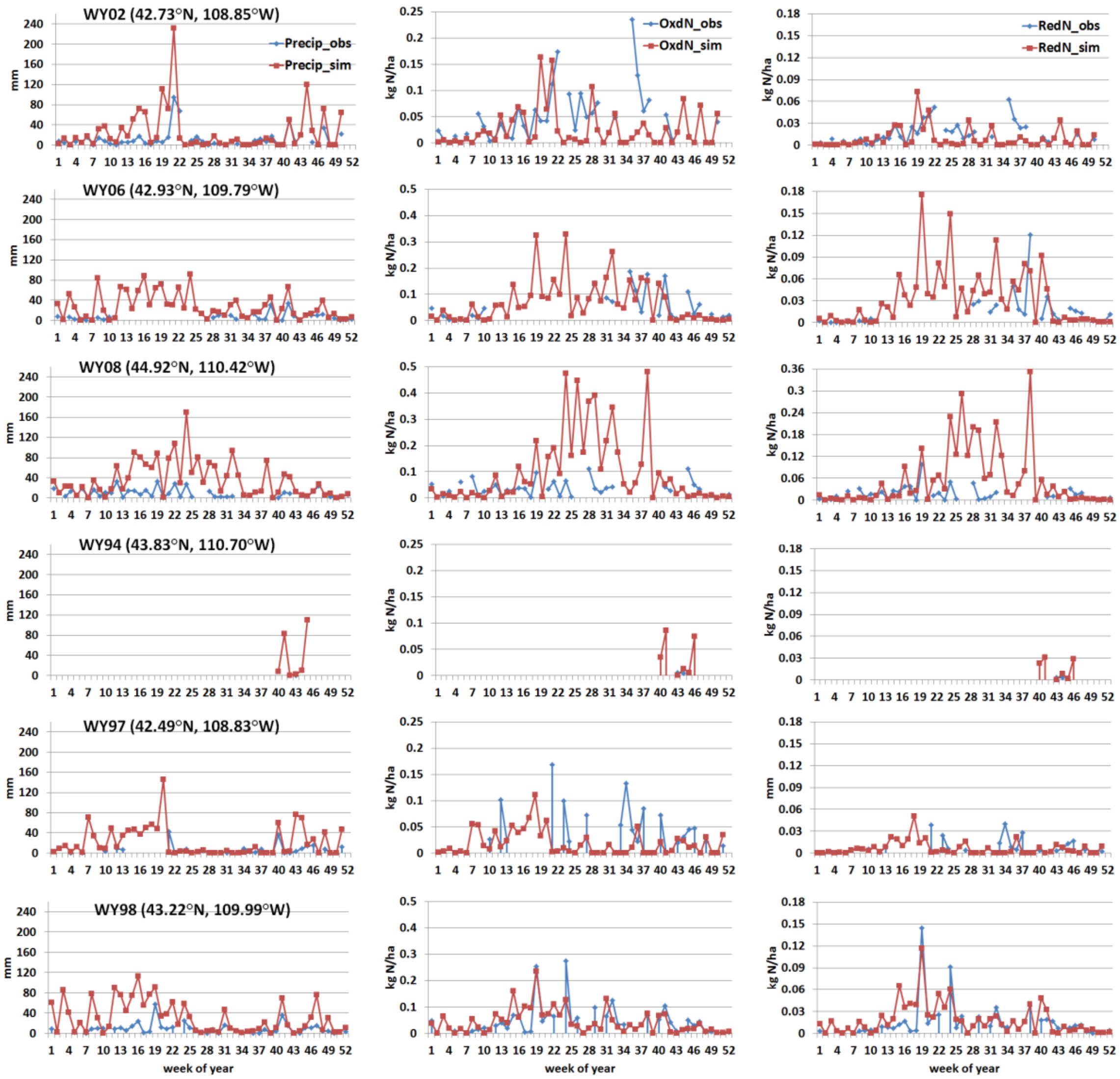

Figure S3. Time series comparison of measured (red lines) precipitation (left panels), wet deposition for oxidized nitrogen (middle panels) as well as wet deposition for reduced nitrogen with corresponding model values (blue lines) on the 6 NTN sites over GYA in 2011. The Grand Teton site (WY94) began operation in September 2011. Due to the incomplete time series these data were excluded from the model evaluation.

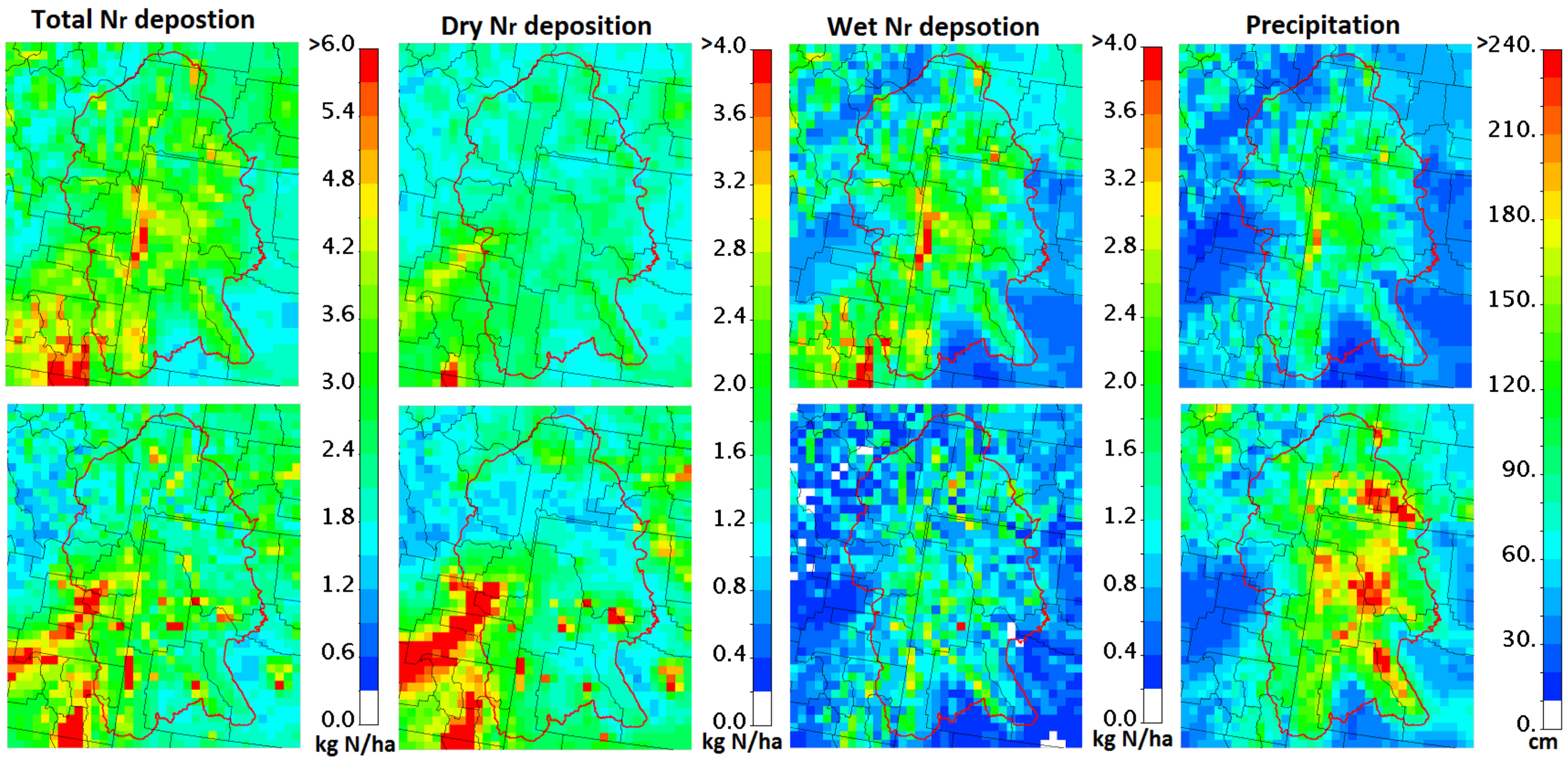

Figure S4. Spatial pattern comparison of annual total, dry, and wet deposition, as well as precipitation from the NADP Total Deposition Map (TDEP, above panel) and corresponding CAMx/WRF simulation results (lower panel) over the GYA area.

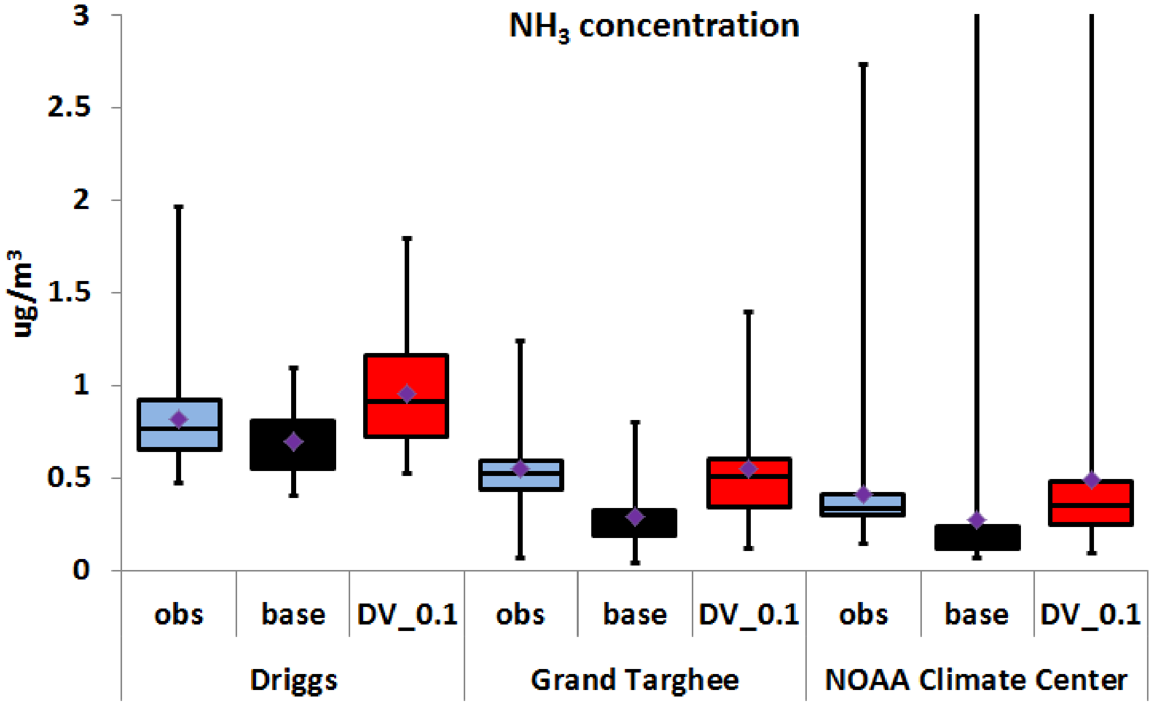

Figure S5. Sensitivity of the NH_3 dry deposition velocity to the simulated NH_3 concentrations at the three core sites during the GrandTReNDS study in July–August 2011.

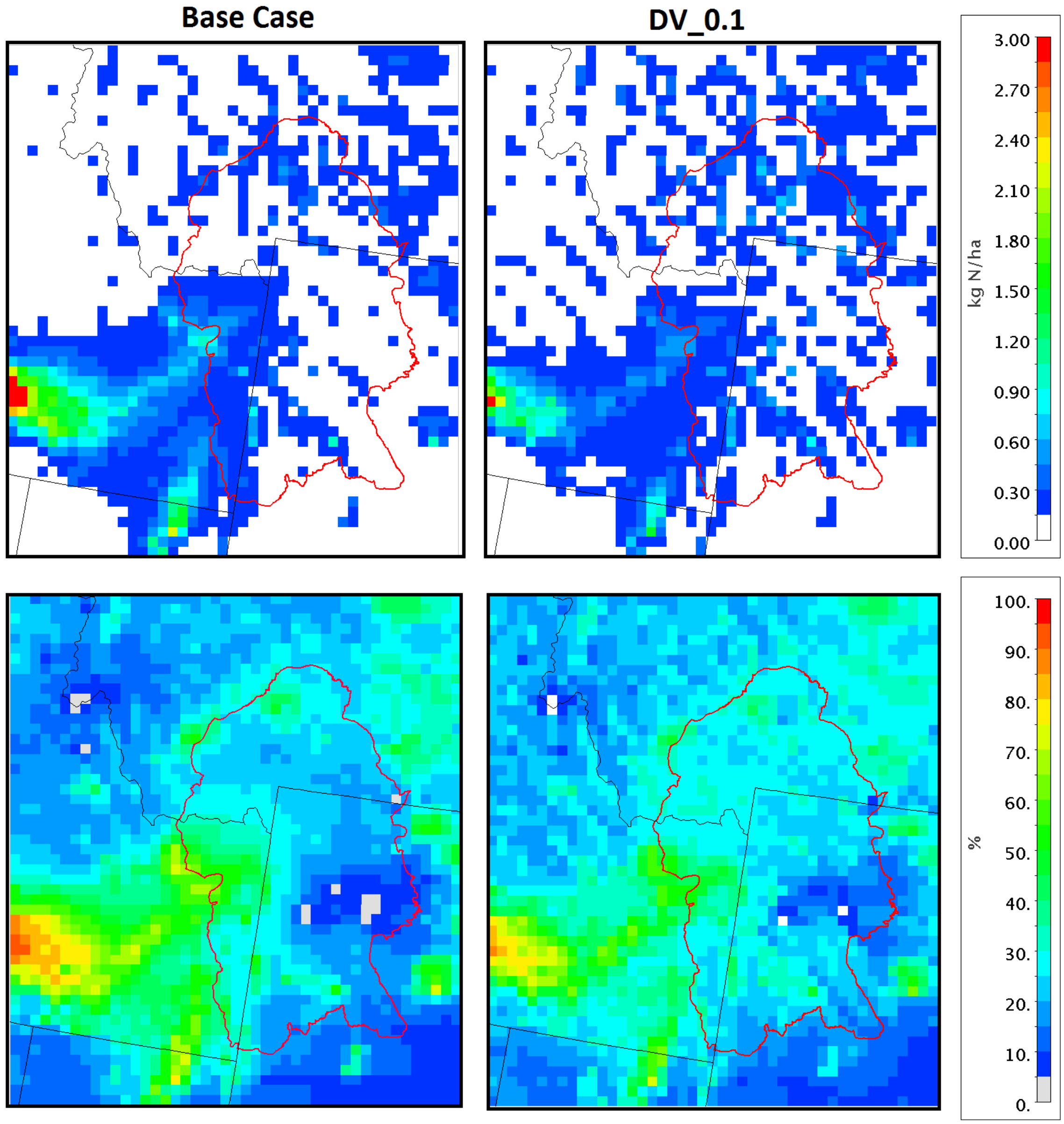

Figure S6. Change of spatial patterns of the simulated total N_r deposition (top panel) as well as contributions from agricultural emissions sector to N_r deposition budget (bottom panel) over the GYA area during July–August 2011 due to the change of NH_3 deposition velocity in CAMx.

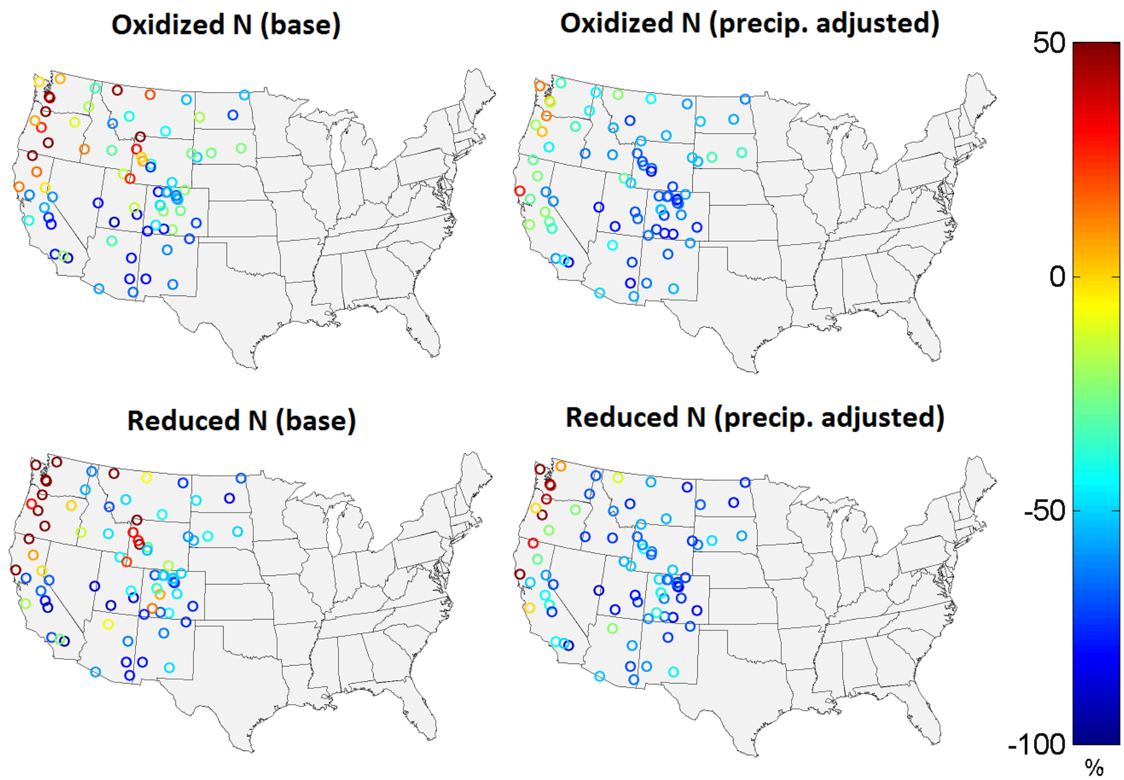

Figure S7. Change of model performance of CAMx wet oxidized and reduced nitrogen deposition simulation in terms of normalized mean bias at NADP NTN sites by implementing the precipitation adjustment technique followed by Appel et al. (2011).

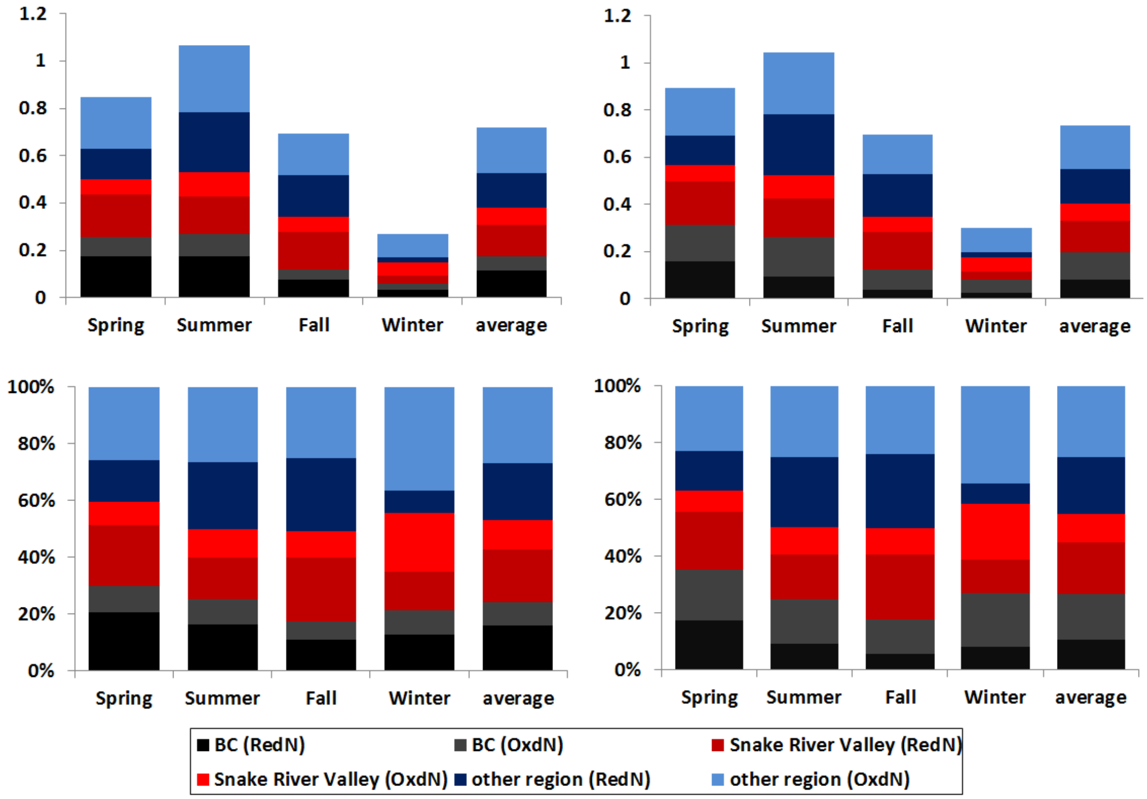

Figure S8. Sensitivity of MOZART (left) or GEOS-Chem (right) boundary conditions to average seasonal source apportionment results in 2011.

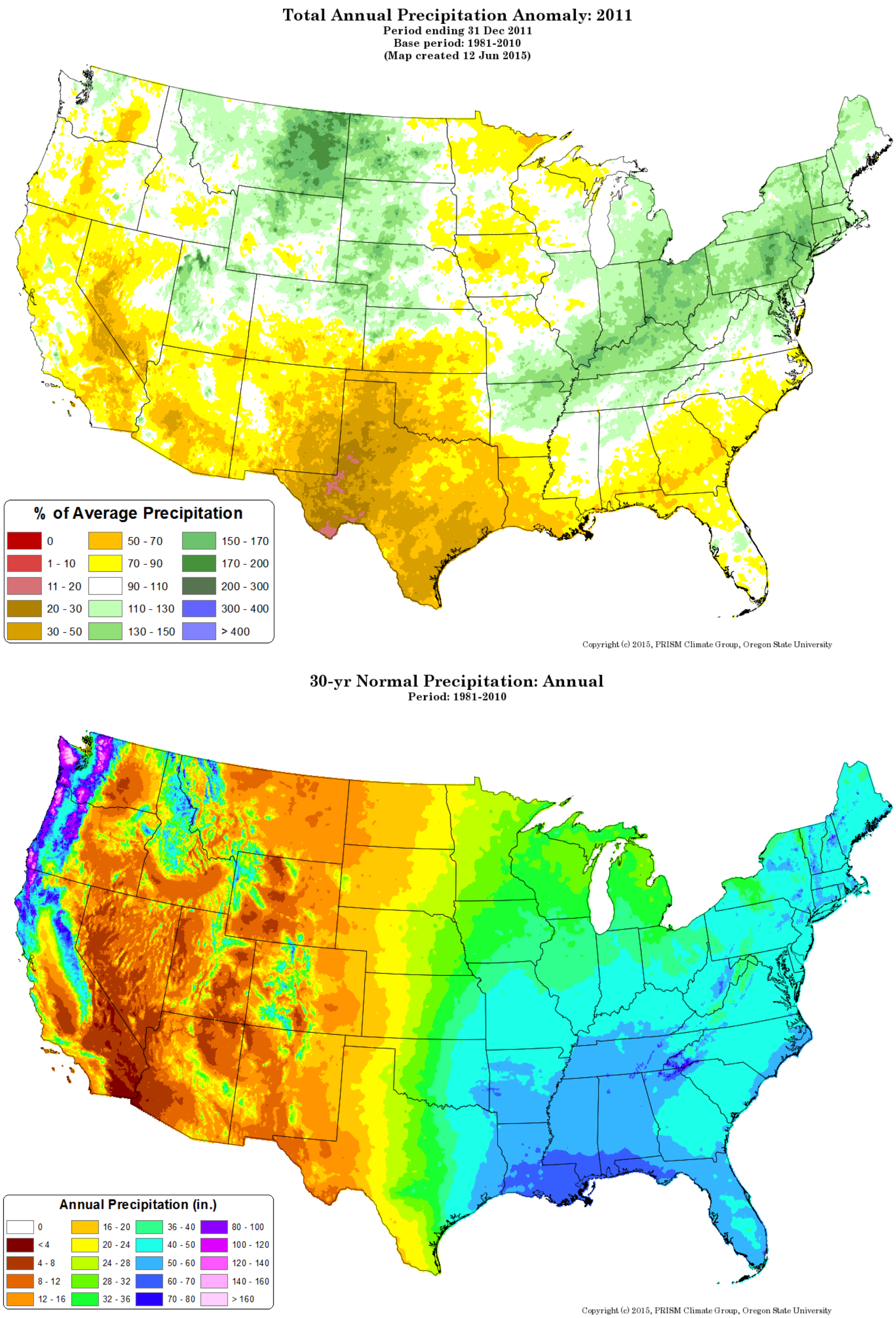

Figure S9. Total annual precipitation anomaly (in percentage) in the year 2011 compared with 30 years (1981-2010) normal annual precipitation from PRISM model

Table S1. Model configuration of WRF-SMOKE-CAMx simulation platform for reactive nitrogen source apportionment study

Meteorological Modeling: WRF-ARW version 3.5.1	
Domain definition	Outer 36km domain (165x129 grid cells); Inner 12km domain (256x253 grid cell); Vertical layer: 37 layers from ground to 50mb with 16 layers within first 1km height
Physics options	Microphysics: Thompson ice, snow and graupel scheme Longwave radiation: RRTMG Shortwave radiation: RRTMG PBL scheme: YSU planetary boundary layer Surface layer scheme: Monin-Obukhov Cumulus parameterization: Kain-Fritsch scheme Land-surface model: Unified NOAH
Data assimilation	Analysis nudging for winds, temperature and mixing ratio above PBL with nudging coefficients $5x10^{-4}$, $3x10^{-4}$ and $1x10^{-5}$ respectively
Initial condition	12km (Grid #218) North American Model (NAM)
Emission Modeling: SMOKE version 3.0	
Anthropogenic emission:	SMOKE version 3.0 with NEI2011v6 MOVES version 2010b for on-road mobile sources
Biogenic emission:	MEGAN version 2.1
Dust emission:	WRAP windblown dust model (WRAP-WBD)
Oil and gas emission:	SMOKE with Independent Petroleum Association of the Mountain States (IPAMS)
Lightning NOx:	ENVIRON generated based on NLCD lightning flash counts
Sea salt:	ENVIRON generated surf zone and open ocean PM emissions
Photochemical Modeling: CAMx version 6.10	
Domain definition	Outer 36km domain (148x112 grid cells); Inner 12km domain (227x230 grid cell); Vertical layer: 25 layer with layer 1 ~24m and model top ~ 19km MSL
Gas phase chemistry:	CB6r2
Deposition scheme:	Zhang et al. (2003)[1] dry deposition scheme CAMx-specific formulation for wet deposition
Aerosol module:	CF scheme for aerosol size distribution
Numeric options:	Gas phase chemistry solver: Euler Backward Iterative (EBI) Vertical advection scheme: Implicit scheme w/ vertical velocity update Horizontal advection scheme: Piecewise Parabolic Method (PPM)
Photolysis rate:	Day-specific ozone column data based on TOMS data measured by OMI
Boundary condition	MOZART global chemistry model (GCM) version 4.6
Initial condition	Fresh start with 15 days spin-up time

[1]Zhang, L., J.R. Brook, and R.Vet, (2003). A revised parameterization for gaseous dry deposition in air-quality models, Atmospheric Chemistry and Physics, 3, 2067-2082, doi:10.5194/acp-3-2067-2003.

Table S2. Summary of 27 tagged regions in CAMx PSAT of this study as well as their corresponding grid counts (36-km) and annual emissions for NH_3 and NOx

Tagged region	Grid counts (36-km domain)	Total emission for nitrogen species (tons/yr)									
		NH3					NOx				
		AG	OG	fire	Other	total	AG	OG	fire	Other	total
1. NW Colorado (Southwest)	42	4,900	0	55	418	5,373	0	12,046	564	54,827	67,437
2. NE Colorado (Southwest)	46	37,041	0	415	3,157	40,613	0	16,002	749	72,830	89,581
3. SE Colorado (Southwest)	54	20,281	0	227	1,728	22,237	0	20,869	976	94,980	116,825
4. SW Colorado (Southwest)	66	6,672	0	75	569	7,315	0	5,504	258	25,051	30,812
5. Upper Green River, WY	49	2,358	0	525	110	2,993	0	11,412	3,016	43,523	57,952
6. Jackson, WY	2	2,375	0	529	111	3,015	0	477	126	1,817	2,420
1. Eastern Wyoming (Other WY)	87	7,298	0	1,625	342	9,265	0	3,013	796	11,490	15,299
2. Western Wyoming (Other WY)	40	18,046	0	4,018	845	22,910	0	10,925	2,887	41,662	55,474
3. Yellowstone (Other WY)	15	1,511	0	336	71	1,918	0	761	201	2,902	3,864
4. Northern Idaho (Northwest)	83	16,887	0	2,193	910	19,991	0	669	6,906	47,036	54,612
5. Snake River Valley, ID	89	43,696	0	5,674	2,356	51,726	0	682	7,030	47,882	55,594
6. Northern Utah	65	12,946	0	69	2,163	15,178	0	10,235	200	92,312	102,747
7. Southern Utah (Southwest)	102	10,083	0	54	1,685	11,822	0	8,907	174	80,338	89,419
8. Nevada	219	5,569	0	825	2,533	8,926	0	189	2,725	107,900	110,814
9. Montana	308	54,343	0	7,531	1,313	63,187	0	13,806	11,510	153,220	178,537
10. Washington (Northwest)	156	44,118	3	825	7,400	52,345	0	467	2,458	268,831	271,757
11. Oregon (Northwest)	203	43,626	0	8,858	5,164	57,649	0	925	28,231	146,062	175,218
12. California	362	203,204	155	3,056	111,240	317,655	0	8,806	9,457	669,421	687,684

13. Mexico (Non-US)	1,969					246,344					782,600
14. New Mexico (Southwest)	247	35,327	0	4,374	2,673	42,374	0	71,863	15,197	170,550	257,609
15. Arizona (Southwest)	236	33,247	0	9,041	8,520	50,808	0	1,489	26,817	250,201	278,506
16. Texas&Oklahoma (Southwest)	800	364,835	44	24,481	39,179	428,539	0	410,736	35,635	1,450,095	1,896,465
17. Canada (Non-US)	1,398					421,830					934,900
18. North Dakota (Eastern US+Great Plains)	152	93,163	0	952	6,995	101,110	0	8,408	1,407	171,869	181,683
19. Pacific (Non-US)	1,820					292					251,698
20. Far East U.S. (Eastern US+Great Plains)	7,500					2,627,200					9,296,000
21. SD_KS_NE (Eastern US+Great Plains)	466	480,670	4	6,245	9,439	496,359	0	96,945	25,572	666,950	789,467
Total:	16,576					**5,128,972**					**16,834,975**

Note: [1]agriculture activities emission; [2]oil and gas activities emission; [3]wildfires and prescribed fires emission; [4]the remaining emission sectors mainly form anthropogenic emission, BVOC emission and lighting NO_x

Table S3. Detail source attribution results of 27 tagged source regions as well as agriculture (AG), oil and gas (OG), wildfires and prescribed fires (fire) and remaining emission source sectors (Other) as well as boundary conditions (BC) to average N_r deposition at each season in 2011

Source Area	**Time**	**Total N (g N ha^{-1} season^{-1})**					**Dry N (percentage)**					**Reduced N (percentage)**				
		AG	**OG**	**fire**	**Other**	**BC**	**AG**	**OG**	**fire**	**Other**	**BC**	**AG**	**OG**	**fire**	**Other**	**BC**
NW Colorado	Winter	0.0	0.0	0.0	0.0		15%	53%	85%	71%		100%	0%	1%	5%	
NW Colorado	Spring	0.1	0.3	0.0	0.4		26%	63%	51%	66%		100%	0%	2%	1%	
NW Colorado	Summer	0.0	0.1	0.0	0.1		19%	60%	61%	51%		100%	0%	3%	2%	
NW Colorado	Fall	0.1	0.3	0.0	0.5		29%	63%	57%	63%		100%	0%	2%	2%	
NE Colorado	Winter	0.0	0.0	0.0	0.0		93%	98%	98%	88%		100%	0%	1%	7%	
NE Colorado	Spring	0.2	0.1	0.0	0.4		20%	67%	51%	60%		100%	0%	2%	2%	
NE Colorado	Summer	0.0	0.0	0.0	0.1		33%	60%	61%	59%		100%	0%	3%	2%	
NE Colorado	Fall	0.6	0.2	0.0	1.1		42%	73%	57%	67%		100%	0%	2%	4%	
SE Colorado	Winter	0.0	0.0	0.0	0.0		80%	98%	98%	85%		100%	0%	2%	8%	
SE Colorado	Spring	0.0	0.0	0.0	0.1		9%	45%	51%	48%		100%	0%	2%	2%	
SE Colorado	Summer	0.0	0.0	0.0	0.1		31%	55%	61%	49%		100%	0%	3%	2%	
SE Colorado	Fall	0.2	0.0	0.0	0.4		32%	64%	57%	62%		100%	0%	2%	4%	
SW Colorado	Winter	0.0	0.1	0.0	0.0		27%	78%	85%	61%		100%	0%	1%	4%	
SW Colorado	Spring	0.1	0.2	0.0	0.2		20%	63%	51%	62%		100%	0%	2%	3%	
SW Colorado	Summer	0.1	0.2	0.0	0.3		10%	43%	61%	39%		100%	0%	3%	3%	
SW Colorado	Fall	0.2	0.3	0.0	0.3		25%	62%	57%	54%		100%	0%	2%	1%	
Upper Green River	Winter	1.2	1.0	2.3	0.7		48%	79%	82%	61%		100%	0%	0%	4%	
Upper Green River	Spring	12.0	3.5	8.8	1.9		32%	54%	51%	41%		100%	0%	1%	5%	
Upper Green River	Summer	8.3	3.2	8.2	4.8		54%	77%	69%	78%		100%	0%	1%	2%	
Upper Green River	Fall	6.9	2.3	6.4	1.9		62%	84%	76%	100%		100%	0%	6%	5%	
Jackson	Winter	0.6	0.0	0.1	4.0		64%	78%	73%	94%		100%	1%	10%	9%	

Jackson	Spring	4.5	0.0	1.2	4.7	60%	96%	44%	78%	100%	0%	0%	3%
Jackson	Summer	3.1	0.0	0.4	5.8	81%	60%	33%	89%	100%	43%	1%	8%
Jackson	Fall	3.6	0.0	3.5	4.5	85%	72%	89%	94%	100%	1%	72%	5%
Eastern Wyoming	Winter	0.0	0.1	0.2	0.0	79%	97%	97%	94%	100%	0%	67%	0%
Eastern Wyoming	Spring	0.5	0.4	1.1	1.1	33%	68%	53%	83%	100%	0%	1%	1%
Eastern Wyoming	Summer	0.1	0.1	0.3	0.0	41%	85%	79%	46%	100%	0%	84%	1%
Eastern Wyoming	Fall	1.3	0.7	3.4	0.0	70%	92%	91%	10%	100%	0%	63%	0%
Western Wyoming	Winter	1.2	0.7	0.6	0.1	70%	84%	82%	99%	100%	0%	69%	0%
Western Wyoming	Spring	10.8	1.9	2.6	0.1	48%	61%	51%	68%	100%	0%	1%	2%
Western Wyoming	Summer	5.3	1.6	46.9	0.5	61%	83%	89%	81%	100%	0%	90%	2%
Western Wyoming	Fall	6.6	1.5	9.9	0.0	73%	87%	85%	90%	100%	0%	71%	4%
Yellowstone	Winter	0.1	0.0	0.2	2.3	82%	92%	70%	81%	100%	0%	55%	5%
Yellowstone	Spring	0.6	0.0	0.9	2.2	68%	75%	53%	65%	100%	0%	1%	1%
Yellowstone	Summer	0.4	0.0	25.7	62.9	85%	90%	79%	75%	100%	0%	98%	1%
Yellowstone	Fall	0.5	0.0	13.9	43.6	86%	93%	94%	94%	100%	0%	97%	3%
Northern Idaho	Winter	0.3	0.0	1.6	0.8	40%	86%	55%	90%	100%	0%	5%	2%
Northern Idaho	Spring	1.7	0.0	3.6	0.0	45%	77%	57%	88%	100%	0%	5%	3%
Northern Idaho	Summer	0.8	0.0	1.9	1.8	57%	60%	56%	82%	100%	0%	12%	2%
Northern Idaho	Fall	2.2	0.0	9.4	15.0	51%	78%	55%	46%	100%	0%	68%	4%
Snake River Valley	Winter	45.7	1.5	11.6	61.1	59%	70%	69%	73%	100%	0%	23%	7%
Snake River Valley	Spring	259.5	1.7	18.0	62.0	65%	52%	54%	57%	100%	0%	18%	2%
Snake River Valley	Summer	230.6	2.3	84.7	43.1	76%	77%	68%	99%	100%	0%	14%	9%
Snake River Valley	Fall	259.3	1.8	66.3	22.0	82%	79%	86%	63%	100%	0%	28%	1%
Northern Utah	Winter	2.8	0.3	3.3	17.2	40%	73%	74%	73%	100%	0%	17%	4%
Northern Utah	Spring	14.7	1.1	6.0	31.8	25%	48%	41%	45%	100%	0%	5%	4%
Northern Utah	Summer	16.8	1.0	5.0	42.9	51%	70%	66%	70%	100%	0%	8%	3%
Northern Utah	Fall	12.4	0.8	3.6	23.9	49%	73%	63%	71%	100%	0%	6%	3%
Southern Utah	Winter	0.6	0.1	3.7	2.4	38%	74%	85%	77%	100%	0%	1%	1%

Southern Utah	Spring	3.6	0.2	4.9	3.5	14%	51%	51%	44%	100%	0%	2%	1%
Southern Utah	Summer	4.6	0.2	9.2	9.5	47%	63%	61%	78%	100%	0%	2%	0%
Southern Utah	Fall	4.6	0.2	7.5	6.0	36%	69%	57%	76%	100%	0%	2%	0%
Nevada	Winter	0.5	0.0	1.4	5.1	26%	54%	70%	65%	100%	0%	2%	3%
Nevada	Spring	3.5	0.1	2.5	12.9	18%	29%	37%	31%	100%	0%	2%	3%
Nevada	Summer	4.4	0.1	4.6	32.3	38%	61%	56%	67%	100%	0%	7%	3%
Nevada	Fall	1.8	0.0	2.3	8.5	43%	64%	53%	64%	100%	0%	10%	4%
Montana	Winter	0.6	0.2	0.8	2.2	47%	76%	82%	81%	100%	0%	4%	8%
Montana	Spring	7.0	0.7	4.0	3.9	34%	61%	54%	69%	100%	0%	1%	5%
Montana	Summer	0.8	0.1	0.9	1.6	38%	61%	55%	75%	100%	0%	6%	4%
Montana	Fall	4.3	0.4	13.3	3.7	57%	82%	56%	61%	100%	0%	68%	3%
Washington	Winter	0.7	0.0	1.6	7.3	49%	80%	55%	78%	100%	1%	5%	6%
Washington	Spring	3.7	0.0	4.4	7.3	50%	67%	61%	75%	100%	1%	4%	4%
Washington	Summer	1.9	0.0	2.0	5.5	41%	65%	56%	65%	100%	7%	12%	4%
Washington	Fall	2.7	0.0	7.7	0.5	48%	71%	70%	98%	100%	1%	11%	0%
Oregon	Winter	1.5	0.1	3.1	5.2	34%	66%	55%	54%	100%	0%	5%	2%
Oregon	Spring	10.4	0.1	8.2	11.0	40%	44%	61%	43%	100%	0%	4%	3%
Oregon	Summer	10.8	0.1	3.8	17.0	54%	73%	56%	71%	100%	0%	12%	0%
Oregon	Fall	6.2	0.1	17.4	2.7	54%	70%	58%	99%	100%	0%	28%	1%
California	Winter	1.2	0.2	4.9	13.2	23%	57%	67%	56%	100%	2%	6%	2%
California	Spring	21.5	0.5	12.0	45.2	12%	31%	47%	26%	100%	3%	7%	2%
California	Summer	29.3	0.6	10.6	56.0	35%	64%	57%	60%	100%	4%	18%	3%
California	Fall	7.0	0.2	5.1	18.5	40%	61%	51%	56%	100%	2%	18%	2%
Mexico	Winter	0.0	0.0	0.3	0.0	78%	83%	76%	100%	1%	1%	15%	3%
Mexico	Spring	0.0	0.0	0.6	1.1	96%	57%	61%	33%	0%	0%	4%	1%
Mexico	Summer	0.0	0.0	0.6	20.2	60%	69%	54%	52%	43%	0%	1%	5%
Mexico	Fall	0.0	0.0	0.7	3.3	72%	58%	75%	41%	1%	0%	36%	6%
New Mexico	Winter	0.0	0.1	0.1	0.3	60%	91%	85%	89%	100%	0%	1%	1%

New Mexico	Spring	0.1	0.1	0.1	0.5	17%	61%	51%	70%	100%	0%	2%	5%
New Mexico	Summer	0.8	0.5	0.2	3.4	21%	41%	61%	40%	100%	0%	3%	8%
New Mexico	Fall	0.6	0.4	0.1	1.5	24%	60%	57%	56%	100%	0%	2%	4%
Arizona	Winter	0.1	0.0	1.9	0.2	41%	82%	78%	89%	100%	0%	1%	3%
Arizona	Spring	1.1	0.1	3.7	0.3	13%	50%	48%	57%	100%	0%	2%	1%
Arizona	Summer	3.0	0.1	7.3	5.8	36%	59%	61%	60%	100%	0%	3%	2%
Arizona	Fall	2.4	0.1	6.0	3.2	29%	66%	57%	70%	100%	0%	2%	2%
Texas & Oklahoma	Winter	0.0	0.0	0.0	0.0	71%	97%	95%	51%	100%	0%	1%	6%
Texas & Oklahoma	Spring	0.4	0.2	0.1	0.7	11%	55%	51%	51%	100%	0%	2%	7%
Texas & Oklahoma	Summer	2.2	1.0	0.2	5.2	28%	52%	61%	52%	100%	0%	3%	8%
Texas & Oklahoma	Fall	2.1	0.5	0.1	1.7	25%	56%	57%	50%	100%	0%	2%	2%
Canada	Winter	0.0	0.0	7.5	2.8	78%	78%	73%	81%	1%	1%	9%	2%
Canada	Spring	0.0	0.0	6.9	1.9	96%	96%	67%	100%	0%	0%	4%	2%
Canada	Summer	0.0	0.0	4.6	0.0	60%	60%	63%	40%	43%	43%	2%	4%
Canada	Fall	0.0	0.0	9.3	1.8	72%	72%	75%	64%	1%	1%	40%	2%
North Dakota	Winter	0.0	0.0	0.0	0.0	85%	94%	90%	93%	100%	0%	5%	6%
North Dakota	Spring	0.9	0.1	0.9	1.2	10%	52%	35%	54%	100%	0%	6%	2%
North Dakota	Summer	0.0	0.0	0.0	0.0	40%	81%	75%	93%	100%	0%	1%	4%
North Dakota	Fall	0.4	0.0	0.1	0.1	68%	86%	60%	100%	100%	0%	15%	0%
Pacific	Winter	0.0	0.0	1.7	1.8	20%	78%	73%	40%	99%	1%	0%	0%
Pacific	Spring	0.0	0.0	1.8	3.2	14%	96%	61%	47%	100%	0%	0%	0%
Pacific	Summer	0.0	0.0	1.5	0.1	40%	60%	68%	99%	100%	43%	0%	0%
Pacific	Fall	0.0	0.0	2.2	1.1	34%	72%	75%	49%	100%	1%	2%	0%
Far East US	Winter	0.0	0.0	0.0	0.0	99%	100%	100%	100%	100%	0%	3%	0%
Far East US	Spring	3.4	0.1	3.1	1.2	8%	55%	35%	87%	100%	1%	6%	2%
Far East US	Summer	0.5	0.2	0.9	2.3	30%	60%	46%	57%	100%	0%	3%	6%
Far East US	Fall	0.3	0.0	0.3	0.3	24%	54%	55%	45%	100%	0%	17%	3%
SD_KS_NE	Winter	0.0	0.0	0.0	0.0	92%	99%	95%	100%	100%	0%	5%	2%

SD_KS_NE	Spring	2.0	0.1	1.4	1.2		12%	55%	35%	61%		100%	0%	3%	0%	
SD_KS_NE	Summer	0.2	0.0	0.2	0.0		34%	59%	59%	64%		100%	0%	2%	0%	
SD_KS_NE	Fall	1.2	0.1	0.1	0.7		48%	67%	55%	86%		100%	0%	12%	0%	
BC	Winter					55.0					50%					58.4%
BC	Spring					235.4					21%					67.8%
BC	Summer					246.3					38%					64.1%
BC	Fall					115.1					52%					63.2%

Supplement File S1

Regional evaluation of CAMx nitrogen deposition in 2011

The Three-State Air Quality Study (3SAQS) performed photochemical grid modeling using the same modeling platform and input files as this study, but with the addition of a nested, 4-km domain centered over Colorado, Utah, and Wyoming (UNC and ENVIRON, 2014). The 3SAQS comprehensive model evaluation report (UNC and ENVIRON, 2015) compared the simulated Nr compound with regard to concentration and deposition against the routine measured data for all sites within the 12-km and 4-km domains. A subset of these results is reproduced in attached Table. With the exception of NH3, the 3SAQS simulation generally reproduced the spatial and temporal variations of the ambient nitrogen concentrations over the western United States with a fractional bias (FB) smaller than ±60% (Boylan and Russell, 2006) (Table S3). However, there were important systematic biases. The oxidized nitrogen gases of NO2 and HNO3 were overestimated with FBs of 29% and 81%, respectively, while NH3 was underestimated by -101%. The CAMx model had different systematic biases for the simulated PNO3 and PNH4 concentration in the different networks. The PNO3 were underestimated at CASTNet and CSN sites while overestimated those at IMPROVE sites. For PNH4, the simulation underestimated data at CASTNet sites while overestimated those at CSN sites. The measured PNH4 at CASTNet and CSN suffered from a negative artifact due to volatilization (Yu et al., 2005) and an accurate model simulation should overestimate these measured concentrations. Note that the dry deposition value provided by CASTNet is not a direct flux measurement but rather the product of a measured concentration and an estimated dry deposition velocity derived from the Multilayer Model (MLM, Cooter and Schwede, 2000). Different deposition velocity algorithm used between MLM and regional CTM model such as CMAQ can impose uncertainties for dry deposition estimates (Schwede and Lear, 2014). Both oxidized and reduced N were underestimated by more than -50% in the wet deposition, with reduced N bias greater than oxidized N (-70% versus -58%, respectively). The biases in particulate compounds did not have any systematic patterns and varied by network and species.

Reference:

Boylan, J.W. and Russell, A.G. (2006). PM and light extinction model performance metrics, goals, and criteria for three-dimensional air quality models. *Atmospheric Environment*, 40(26), pp.4946-4959.

Cooter, E.J. and Schwede, D.B., (2000). Sensitivity of the National Oceanic and Atmospheric Administration multilayer model to instrument error and parameterization uncertainty. *Journal of Geophysical Research: Atmospheres*, 105(D5), pp.6695-6707.

Schwede, D. B., and Lear, G. G. (2014). A novel hybrid approach for estimating total deposition in the United States. Atmospheric Environment, 92, 207-220.

UNC-Chapel Hill and ENVIRON International Corporation (2014), *Three-State Air Quality Modeling Study (3SAQS) – Final modeling protocol: 2011 emissions & air quality modeling platform*, Available at : http://vibe.cira.colostate.edu/wiki/Attachments/Modeling/3SAQS_2011_WRF_MPE_v8_draft_Aug04_2014.pdf.

UNC-Chapel Hill and ENVIRON International Corporation (2015), *Three-State Air Quality Modeling Study (3SAQS) – Model performance evaluation (simulation year 2011)*, Available at: http://vibe.cira.colostate.edu/wiki/Attachments/Modeling/3SAQS_Base11a_MPE_Final_18Jun2015.pdf

Table. Summary of CAMx model performance for nitrogen compound concentrations and deposition simulations at different network sites over the WRAP region, evaluated by 3SAQS study*

Species	Network	Domain resolution	Mean Obs	Mean Sim	R	NMB (%)	NME (%)	FB (%)	FE (%)
Gaseous N_r concentration evaluation									
NO_2 (ppb)	AQS	4km	9.6	13.7	N.A.	58	93	29	63
NH_3 (ppb)	AMoN	4km	1.2	0.42	0.71	-66	69	-101	115
Particulate matter N_r concentration evaluation									
PNO_3(ug m^{-3})	CASTNet[1]	12km	0.51	0.46	N.A.	-9	64	-12	74
	CSN	12km	1.63	1.27	N.A.	-22	66	-30	75
	IMPROVE	12km	0.34	0.44	N.A.	30	94	31	83
PNH_4(ug m^{-3})	CASTNet[2]	12km	0.34	0.33	N.A.	-4	43	-7	41
	CSN	12km	0.71	0.77	N.A.	8	70	26	64
Average N_r dry deposition evaluation									
HNO_3(kg N ha^{-1})	CASTNet	4km	0.0084	0.0195	0.45	130	131	81.	83
PNO_3(kg N ha^{-1})	CASTNet	4km	0.0005	0.0007	0.10	28	84	15	76
PNH_4(kg N ha^{-1})	CASTNet	4km	0.0016	0.0023	0.21	26	53	27	49
Accumulated annual N_r wet deposition evaluation									
PNO_3(kg N ha^{-1})	NTN	12km	0.58	0.36	0.77	-38	40	-58	60
PNH_4(kg N ha^{-1})	NTN	12km	0.91	0.47	0.71	-48	52	-70	79

*For more detailed model performance statistics, refer to UNC and Environ (2015), 1-the measured PNO_3 at CASTNet sites including fine and coarse mode, which should be greater than CAMx counterparts with only fine particulate nitrate, 2-the measured PNH_4 at CASTNet sites has negative bias so is a lower bound of "true" particulate ammonium.