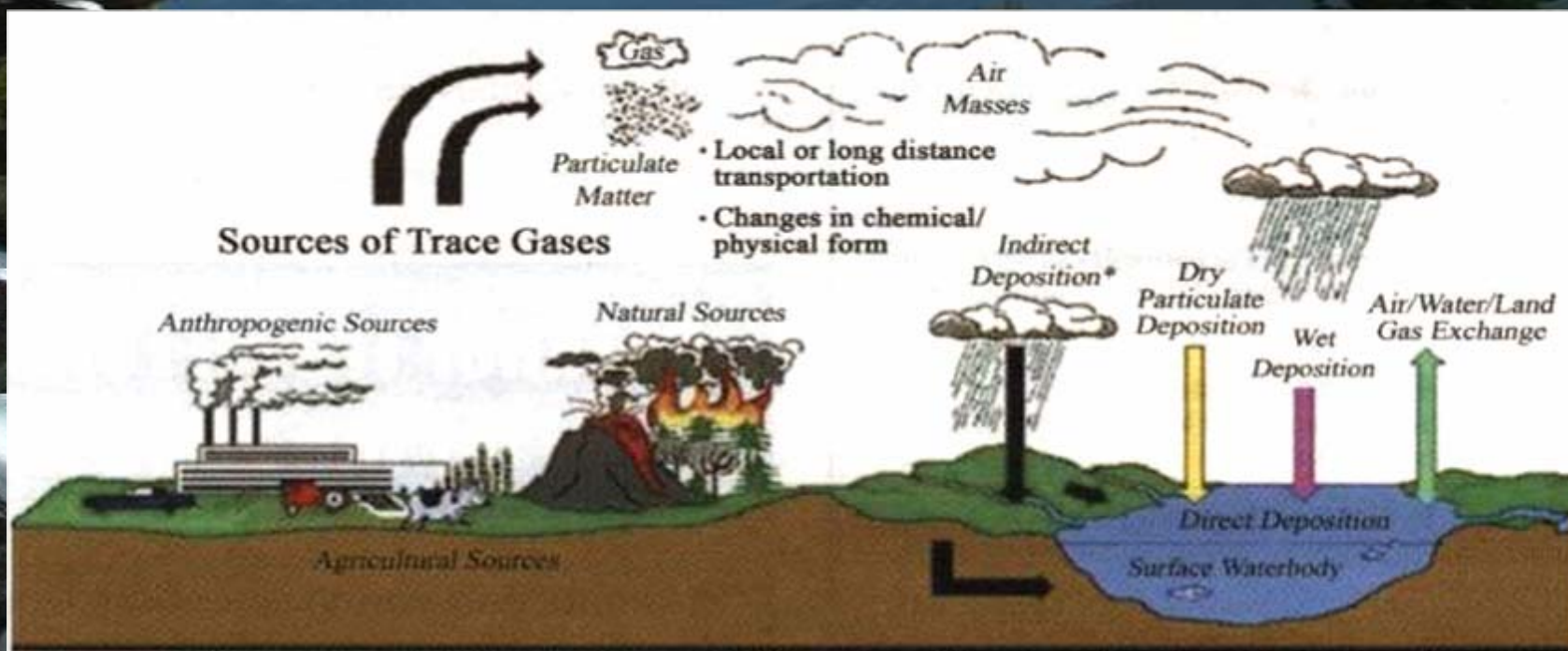


# ROcky Mountain Atmospheric Nitrogen and Sulfur study (ROMANS)

Rocky Mountain National Park (ROMO) is experiencing a number of deleterious effects due to atmospheric nitrogen and sulfur compounds. These effects include visibility degradation, changes in ecosystem function and surface water chemistry from atmospheric deposition, and human health concerns due to elevated ozone concentrations



# ROMANS OBJECTIVES

- Characterize the atmospheric concentrations of sulfur and reactive nitrogen species in gaseous, particulate and aqueous phases along the east and west sides of the Continental Divide
  - GAS:  $\text{SO}_2$ ,  $\text{NH}_3$ ,  $\text{NO}_x$  ( $\text{NO} + \text{NO}_2$ ),  $\text{NO}_y$  ( $\text{HNO}_3$ , PAN, etc), Amines-?
  - PARTICLE:  $\text{NH}_4$ ,  $\text{SO}_4$ ,  $\text{NO}_3$ , Organic Nitrogen?
  - WET:  $\text{NH}_4$ ,  $\text{SO}_4$ ,  $\text{NO}_3$ , Organic Nitrogen
- Identify the relative contributions to atmospheric sulfur and nitrogen species in RMNP from within and outside of the state of Colorado.
- Identify the relative contributions to atmospheric sulfur and nitrogen species in RMNP from more emission sources along the Colorado Front Range versus other areas within Colorado.
- Identify the relative contributions to atmospheric sulfur and nitrogen species from mobile sources, agricultural activities, large and small point sources within the state of Colorado.

# What isn't measured in routine deposition monitoring networks?

- $\text{NH}_3$
- Organic nitrogen either in wet or dry (gas or particle phase) in its reduced, oxidized or biological forms
  - $\text{NO}_2$ , peroxyacetyl nitrate (PAN) and related alkyl nitrates etc
  - Aliphatic amines etc
  - Proteins, amino acids, etc

# MATRIX OF MEASUREMENT NEEDS

	WET	GAS	PARTICLE	Temporal scale (gas/particle)
$\text{SO}_2/\text{SO}_4^{-2}$	*****	****	*****	Min/hr/day/week
$\text{NO}_2/\text{HNO}_3^-/\text{NO}_3^-$	****	****(***)CASTNET)	****(***)CASTNET)	Min/hr/day/week
$\text{NH}_3/\text{NH}_4^-$	***	***	***	Min/hr/day/week
<b>Total ON</b>	***	*	*	Integrated sample/event based
$\text{ON}_r$	* (markers)	*	* (markers)	?
$\text{ON}_o$	* (markers)	***	***	Min/hr/day/week (gas/part) Event for markers
$\text{ON}_b$	* (markers)	**	*	Integrated samples

\*\*\*\*\* Measure with high degree of accuracy

\*\*\*\* Measure with reasonable accuracy

\*\*\* Measure with low accuracy

\*\* Research monitoring

\* Currently cannot do

Note: measurements should be event based for wet deposition and gases and particles measured at least on a 24 hr schedule.

## Core site in RMNP

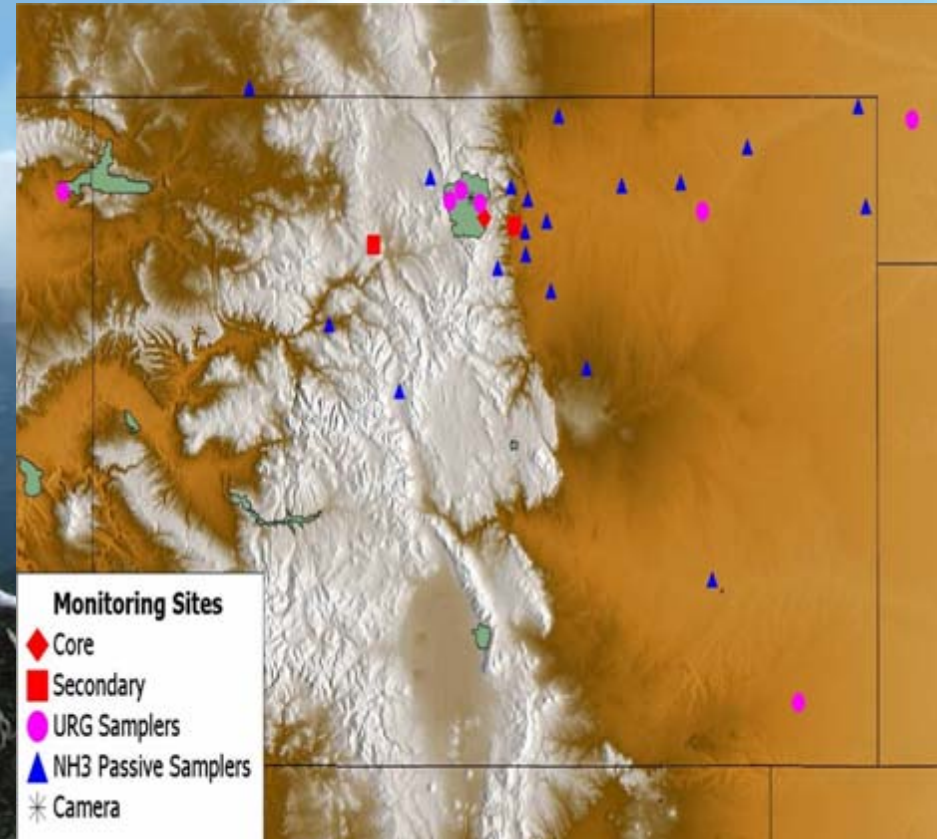
- Particle, gas, wet deposition,
- meteorology measurements
- High time resolution

## Secondary sites

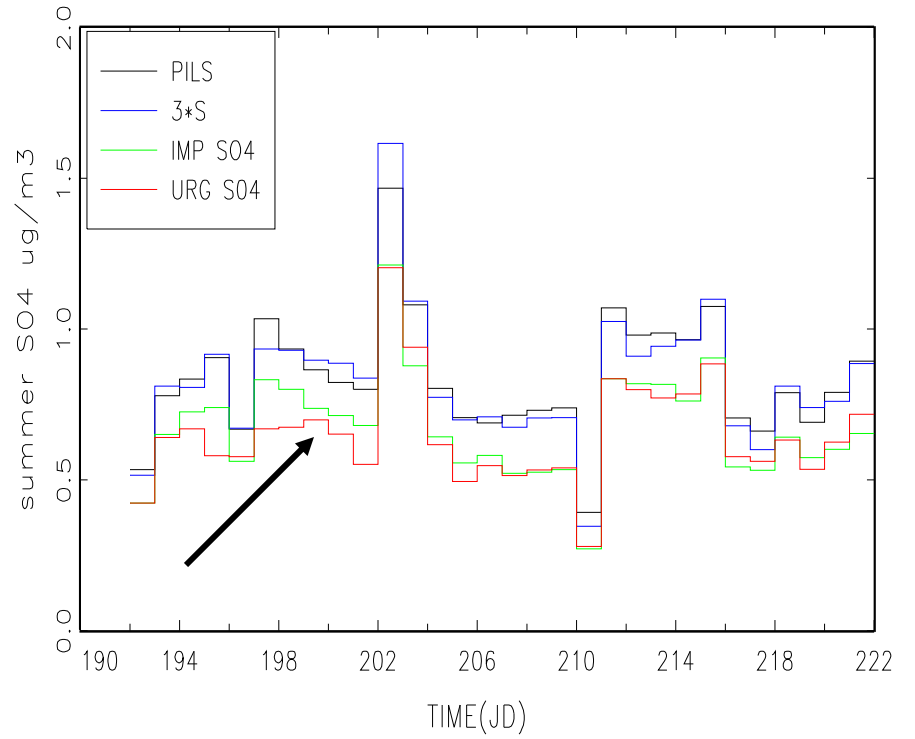
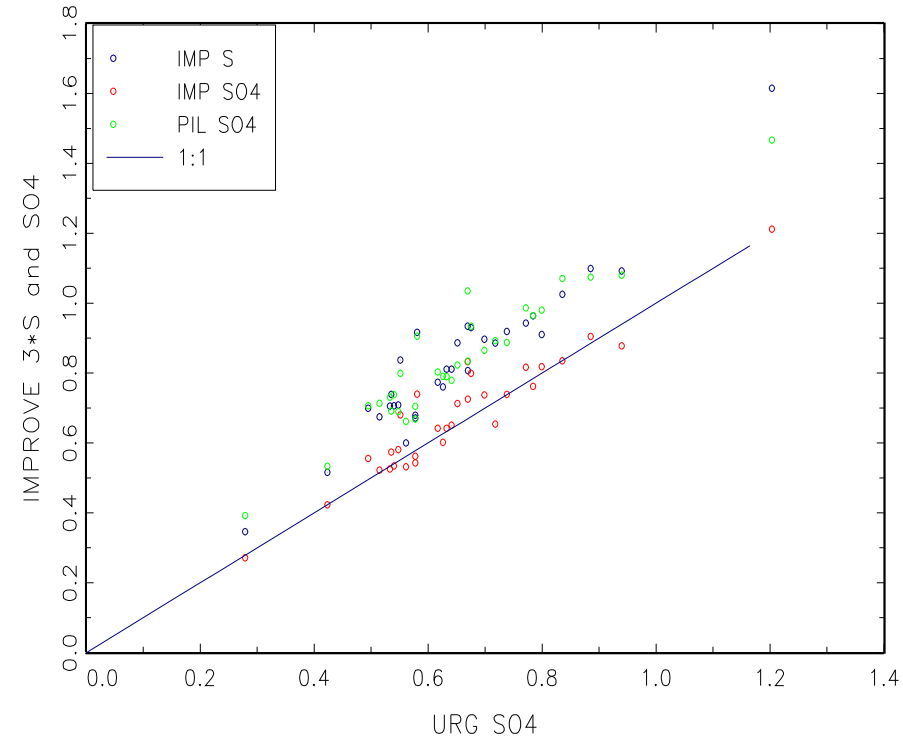
- Lyons and Gore Pass
- Daily time resolution
- Characterize air masses on east and west slopes

## Additional daily monitoring sites

- Within RMNP
- Near state boundaries
- Weekly NH<sub>3</sub> monitoring sites

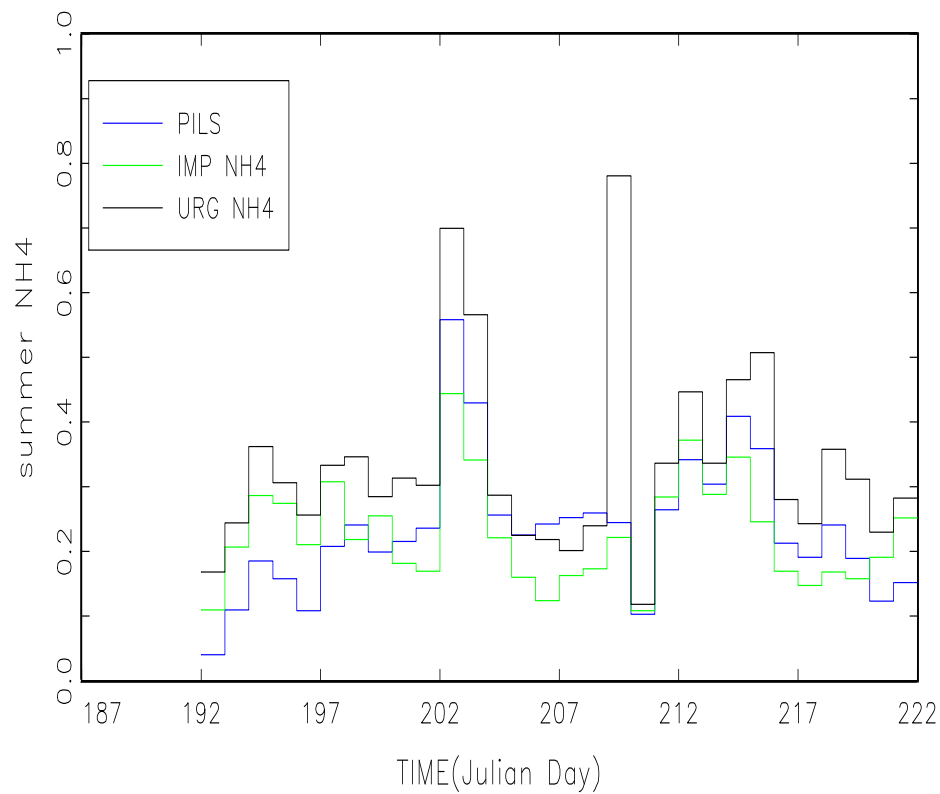
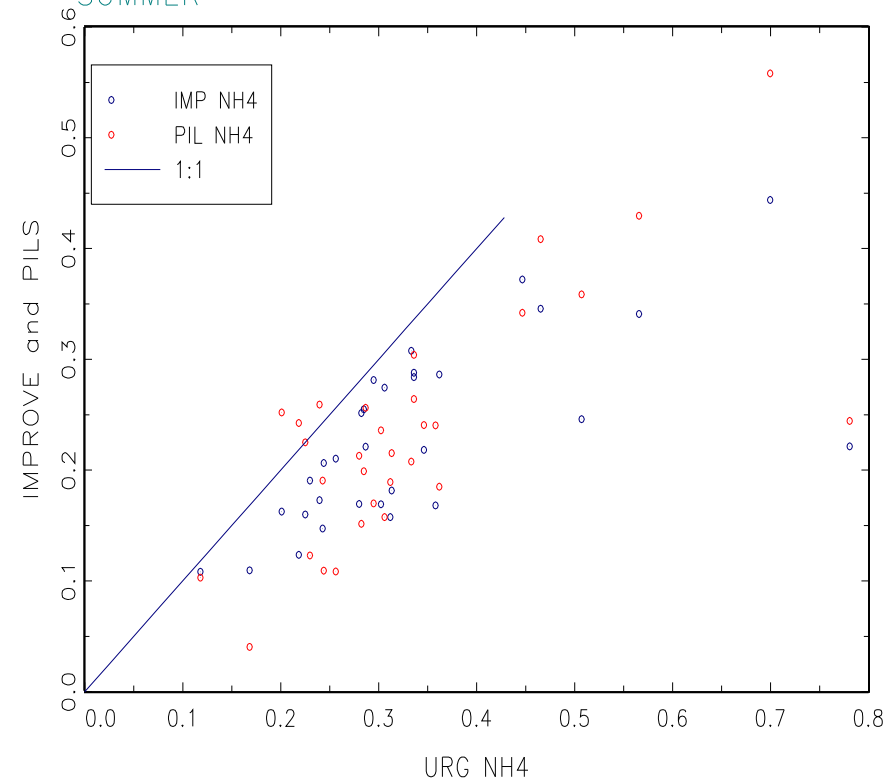


# SUMMER



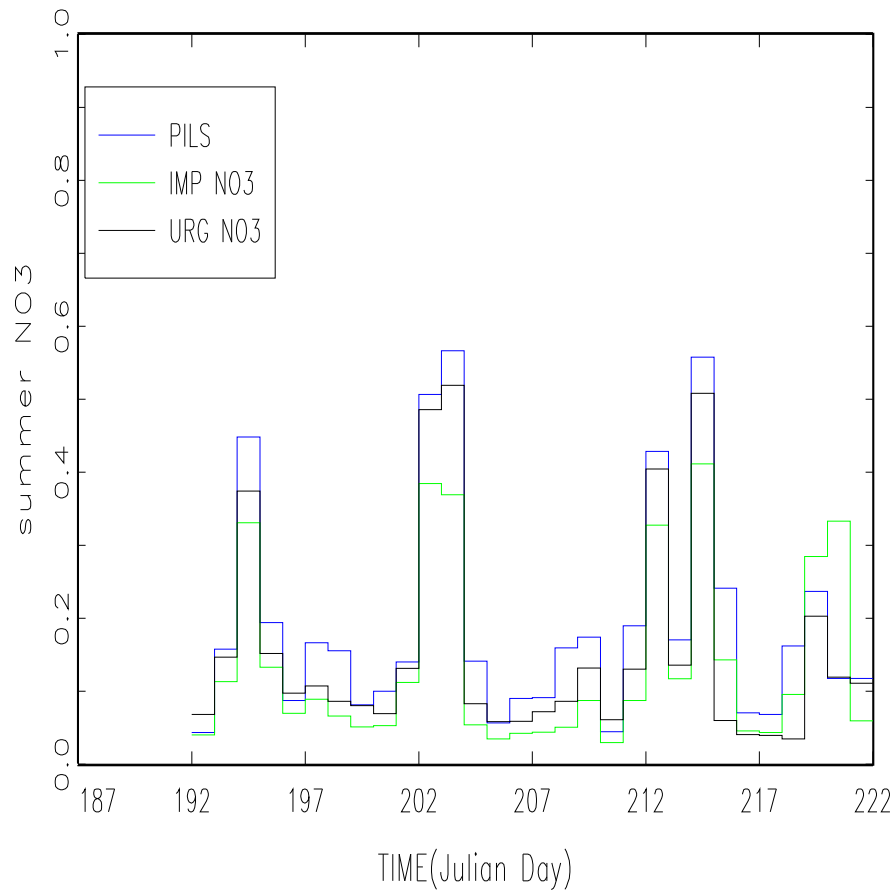
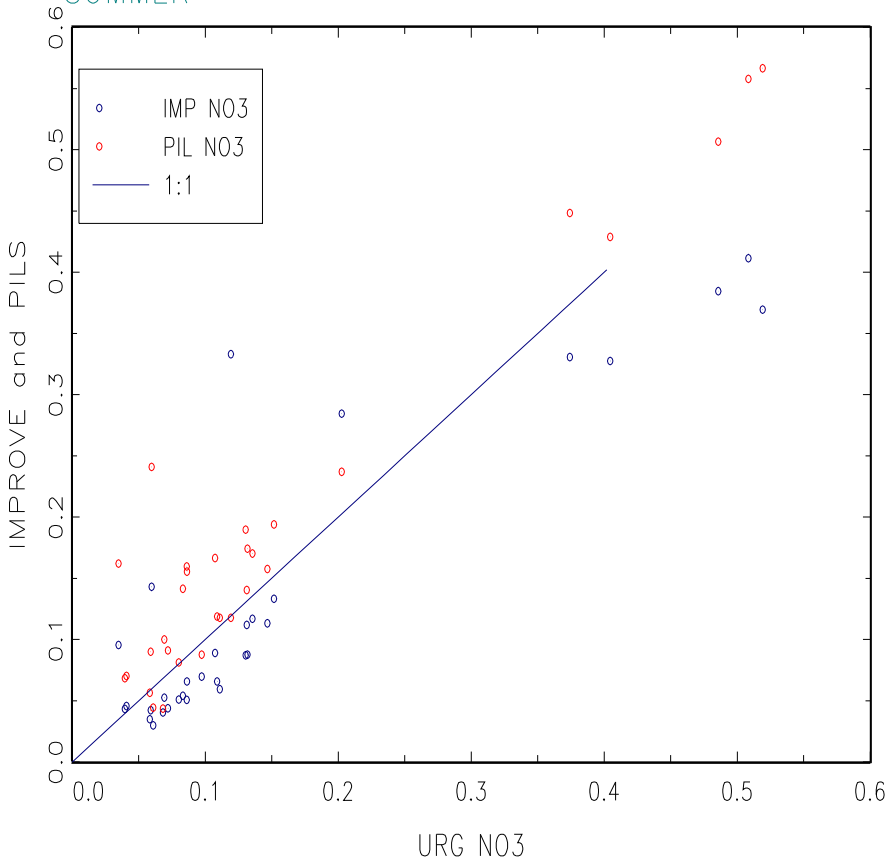
Variable	Mean	Std_Dev	Variance	Minimum	Maximum	Valid
<b>3*S</b>	<b>0.83</b>	<b>0.22</b>	<b>0.05</b>	<b>0.35</b>	<b>1.62</b>	<b>31</b>
<b>SO4I</b>	<b>0.68</b>	<b>0.17</b>	<b>0.03</b>	<b>0.27</b>	<b>1.21</b>	<b>31</b>
<b>SO4U</b>	<b>0.65</b>	<b>0.17</b>	<b>0.03</b>	<b>0.28</b>	<b>1.20</b>	<b>31</b>
<b>SO4PIL</b>	<b>0.84</b>	<b>0.20</b>	<b>0.04</b>	<b>0.39</b>	<b>1.47</b>	<b>31</b>

SUMMER



Variable	Mean	Std_Dev	Variance	Minimum	Maximum	Valid
NH4I	0.23	0.08	0.01	0.11	0.44	31
NH4U	0.33	0.14	0.02	0.12	0.78	31
NH4PIL	0.23	0.11	0.01	0.04	0.56	31

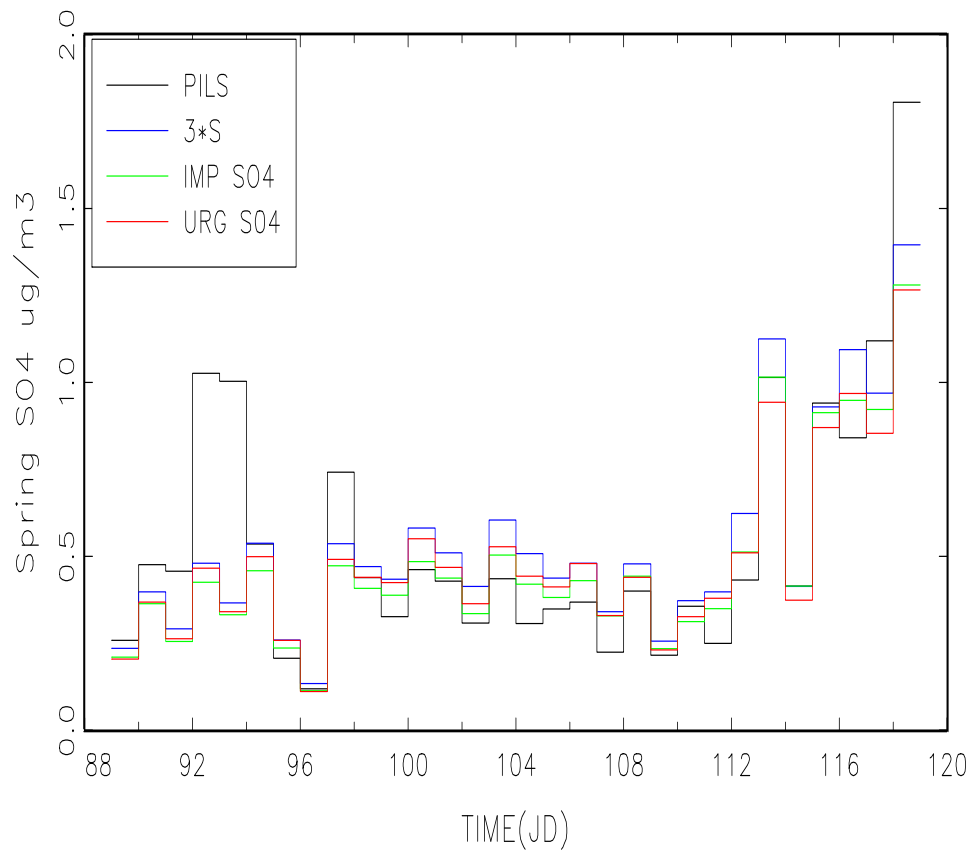
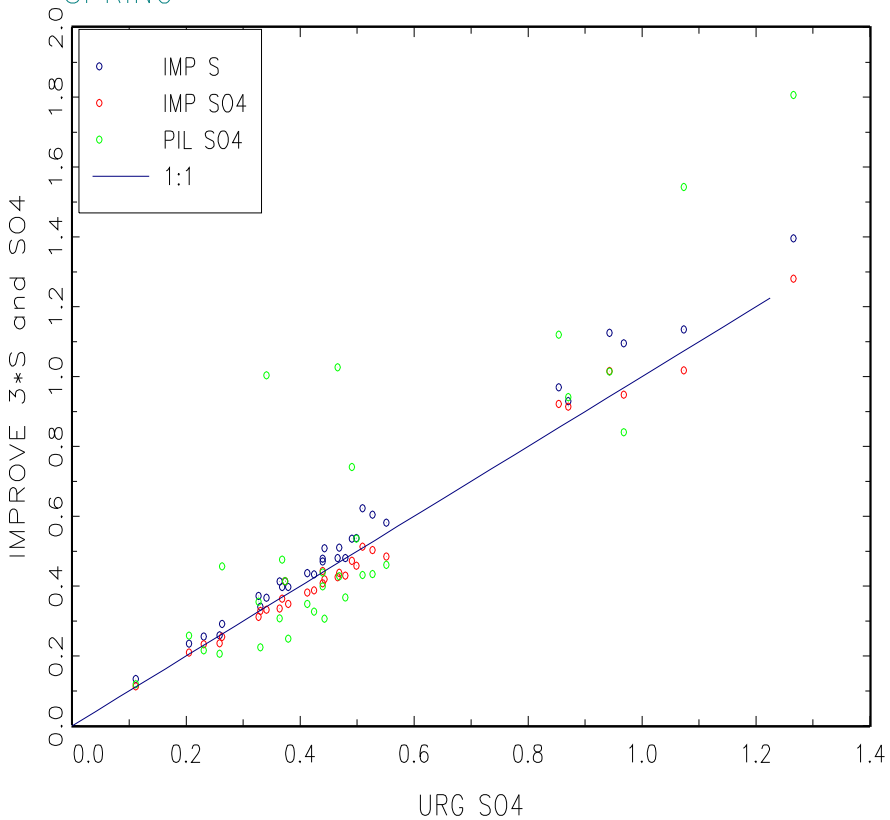
SUMMER



Variable	Mean	Std_Dev	Variance	Minimum	Maximum	Valid
NO3I	0.13	0.12	0.02	0.03	0.41	31
NO3U	0.15	0.14	0.02	0.03	0.52	31
NO3PIL	0.19	0.15	0.02	0.04	0.57	31

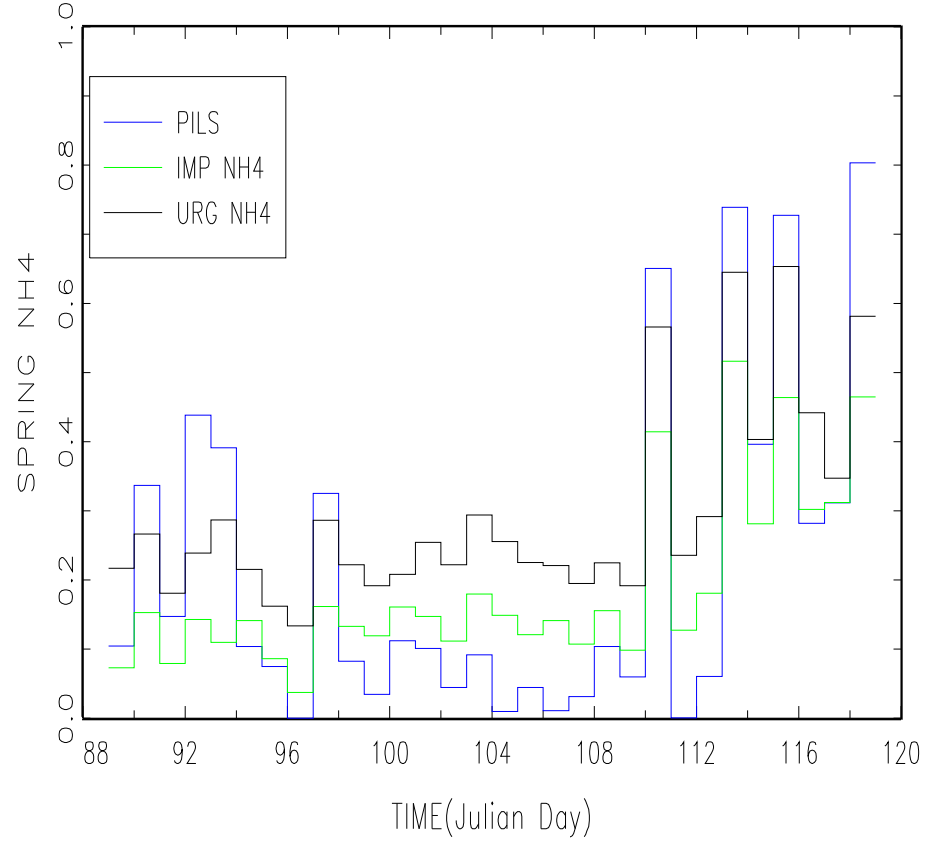
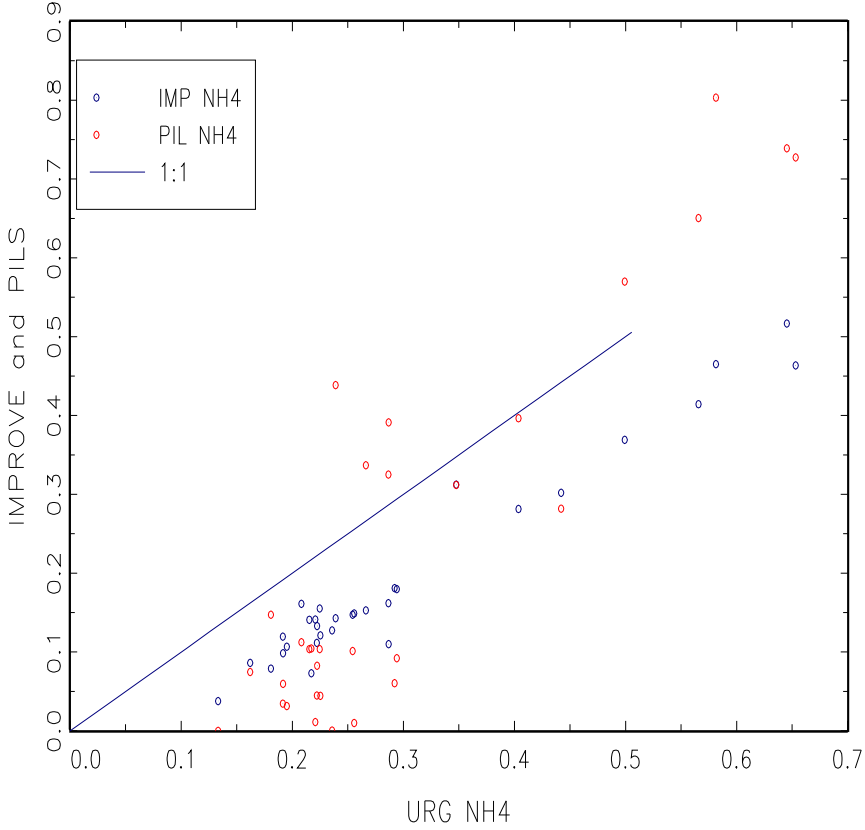


# SPRING



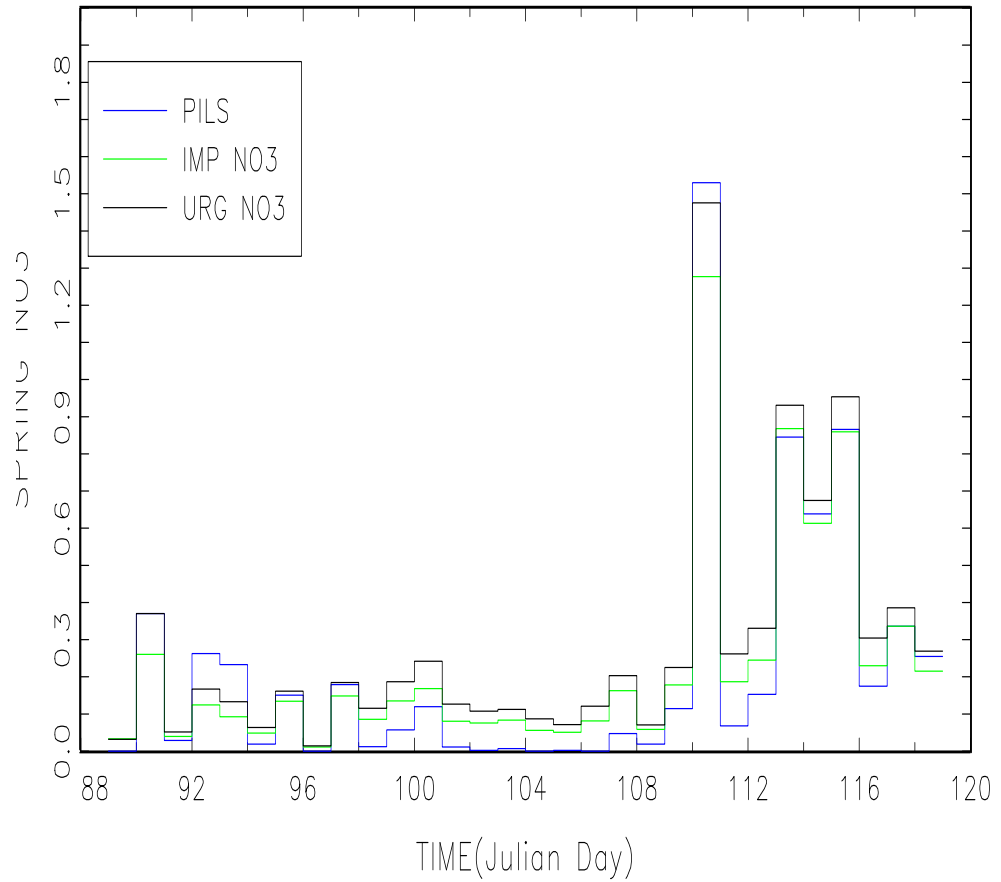
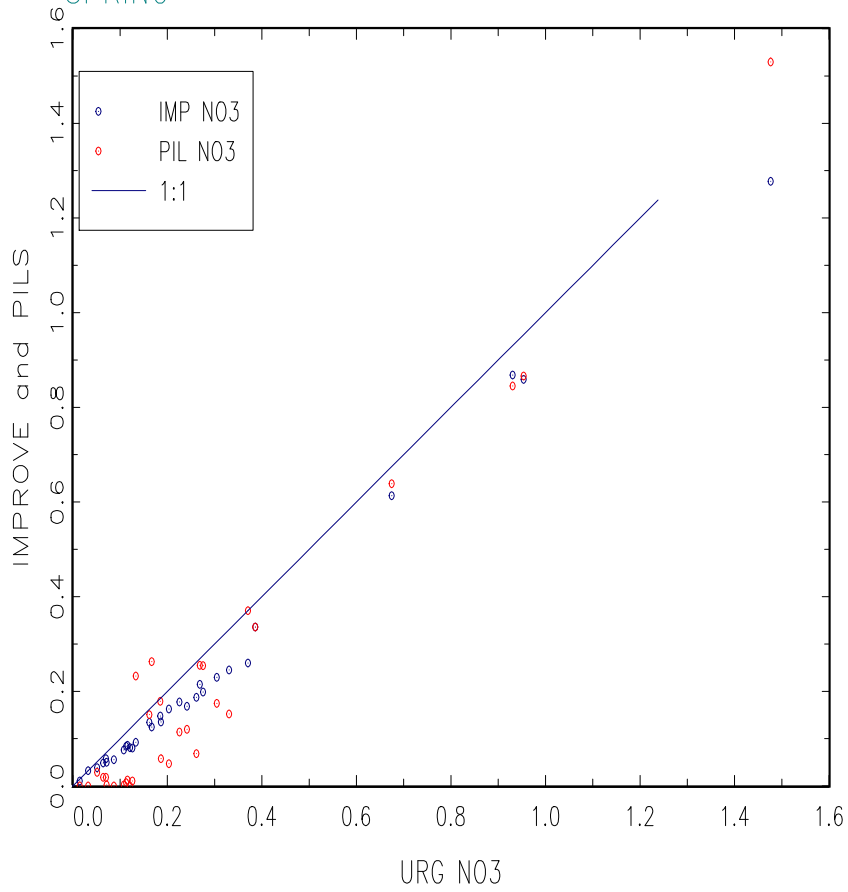
Variable	Mean	Std_Dev	Variance	Minimum	Maximum	Valid
3*S	<b>0.56</b>	<b>0.30</b>	<b>0.09</b>	<b>0.13</b>	<b>1.40</b>	<b>31</b>
SO4I	<b>0.49</b>	<b>0.28</b>	<b>0.08</b>	<b>0.11</b>	<b>1.28</b>	<b>31</b>
SO4U	<b>0.51</b>	<b>0.27</b>	<b>0.07</b>	<b>0.11</b>	<b>1.27</b>	<b>31</b>
SO4PIL	<b>0.57</b>	<b>0.40</b>	<b>0.16</b>	<b>0.12</b>	<b>1.81</b>	<b>31</b>

SPRING



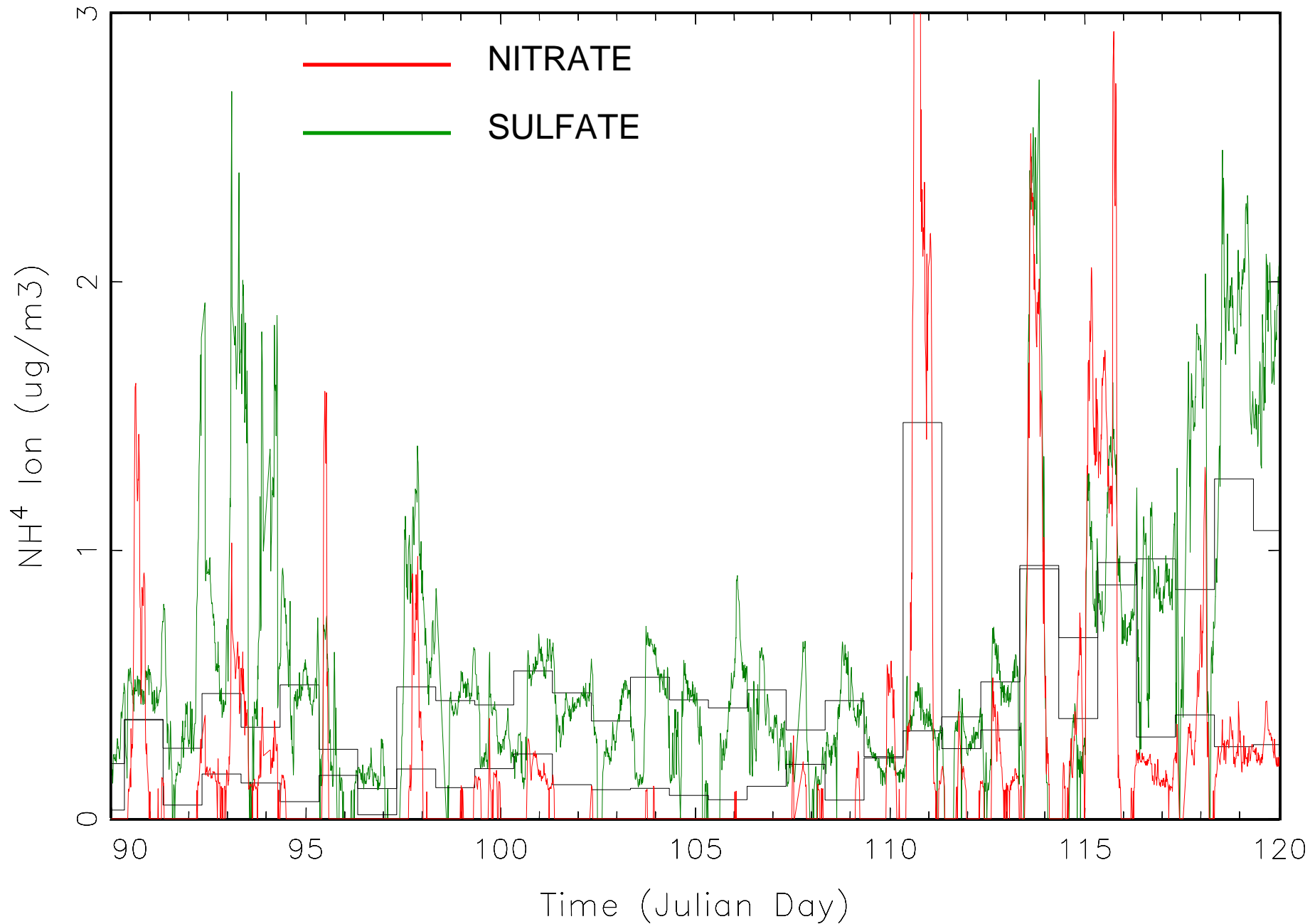
Variable	Mean	Std_Dev	Variance	Minimum	Maximum	Valid
NH4I	0.19	0.13	0.02	0.04	0.52	31
NH4U	0.30	0.14	0.02	0.13	0.65	31
NH4PIL	0.23	0.25	0.06	0.00	0.80	31

SPRING



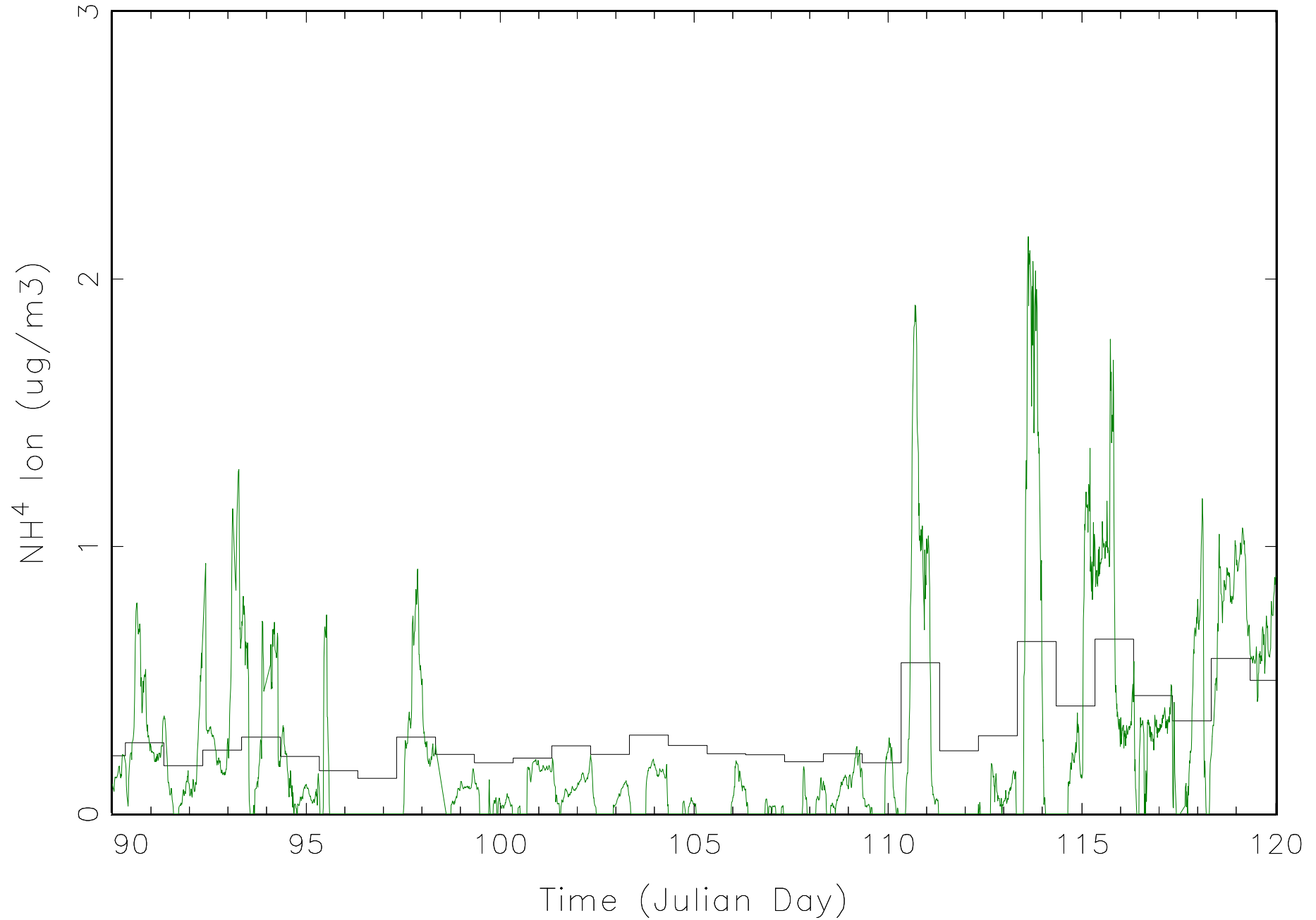
Variable	Mean	Std_Dev	Variance	Minimum	Maximum	Valid
<b>NO3I</b>	<b>0.23</b>	<b>0.29</b>	<b>0.08</b>	<b>0.01</b>	<b>1.28</b>	<b>31</b>
<b>NO3U</b>	<b>0.28</b>	<b>0.32</b>	<b>0.10</b>	<b>0.01</b>	<b>1.48</b>	<b>31</b>
<b>NO3PIL</b>	<b>0.22</b>	<b>0.34</b>	<b>0.11</b>	<b>0.00</b>	<b>1.53</b>	<b>31</b>

**spring**

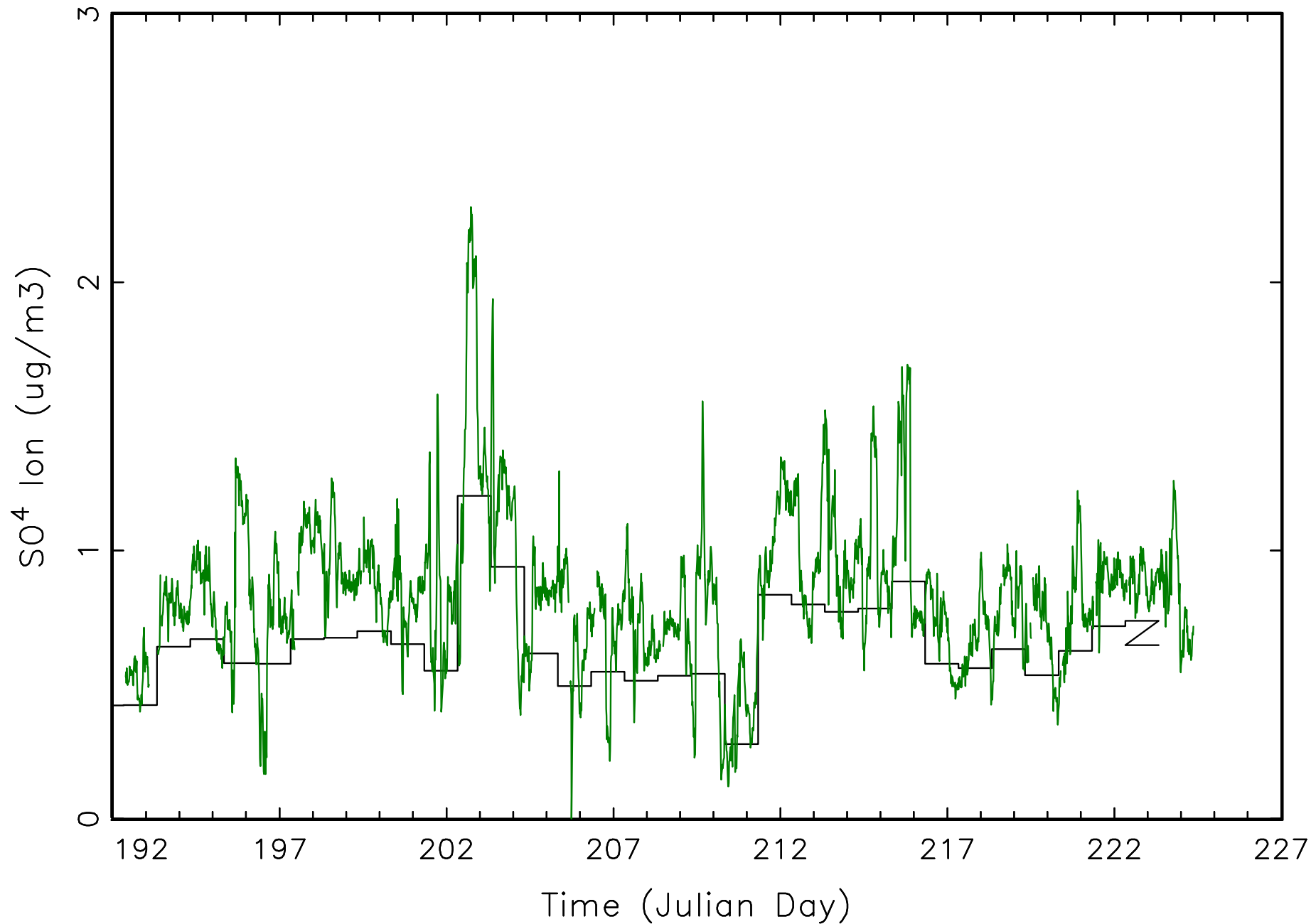


spring

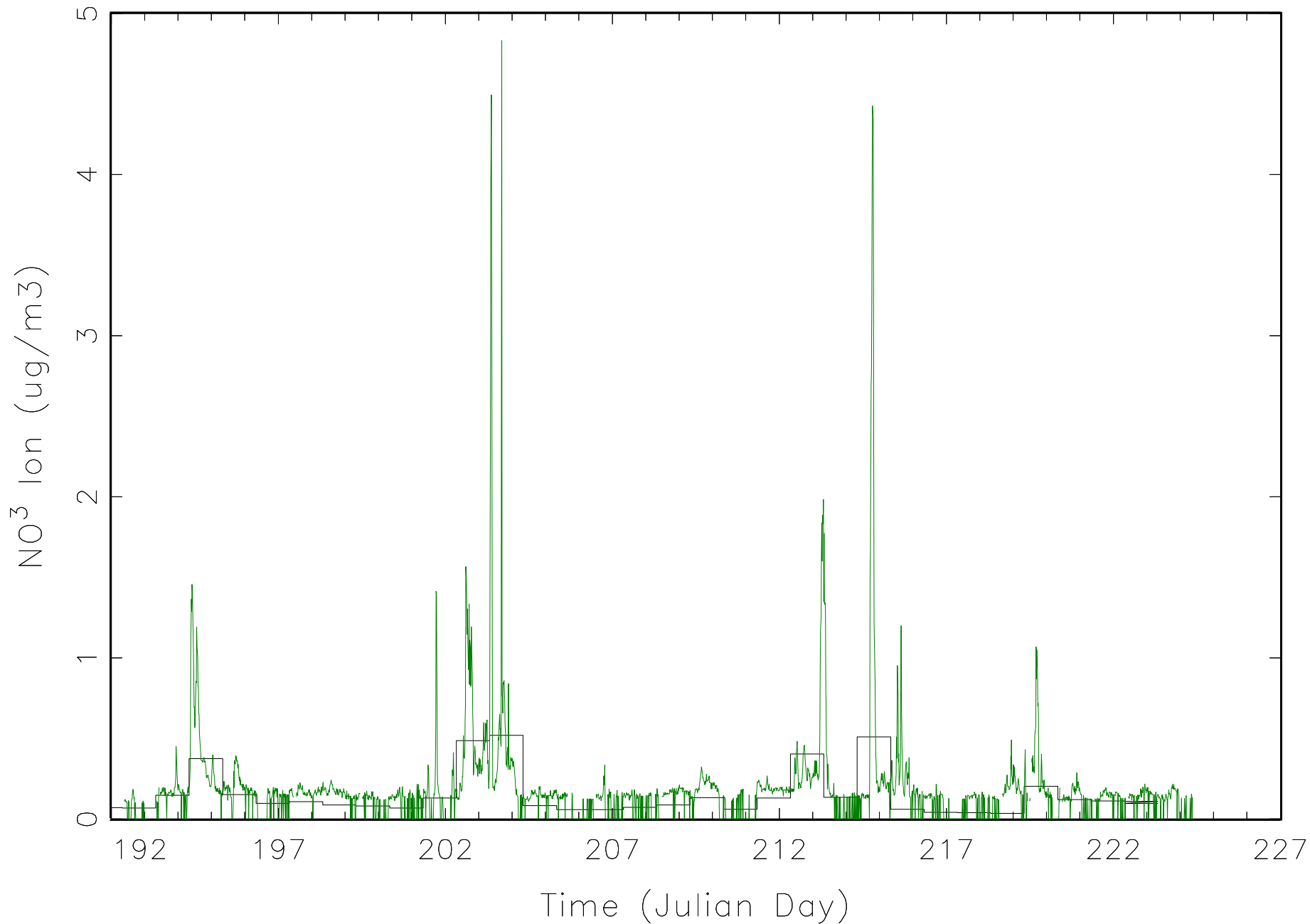
pils and urg NH4



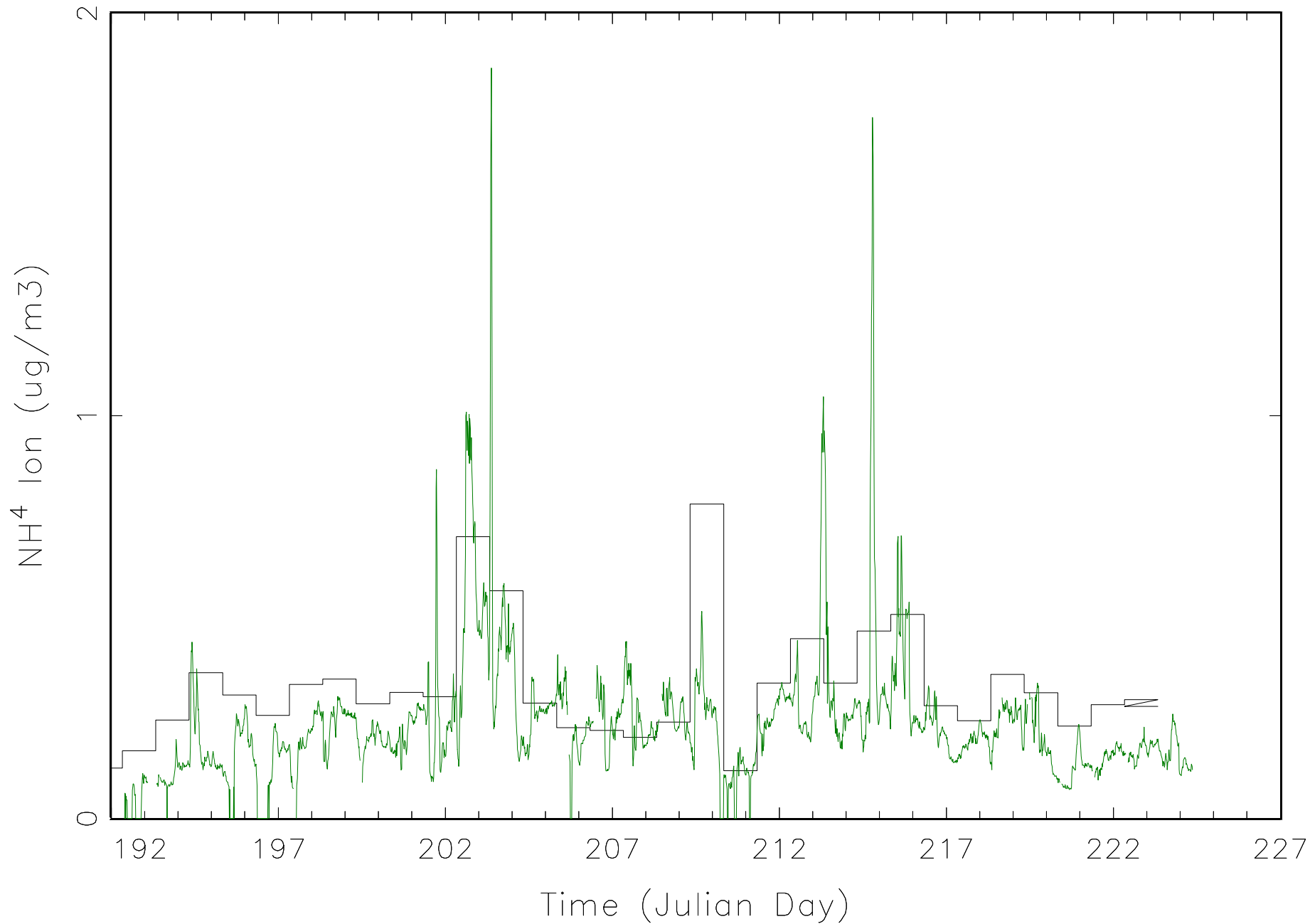
# Summer pils and URG S04



# Summer pils and URG NO3

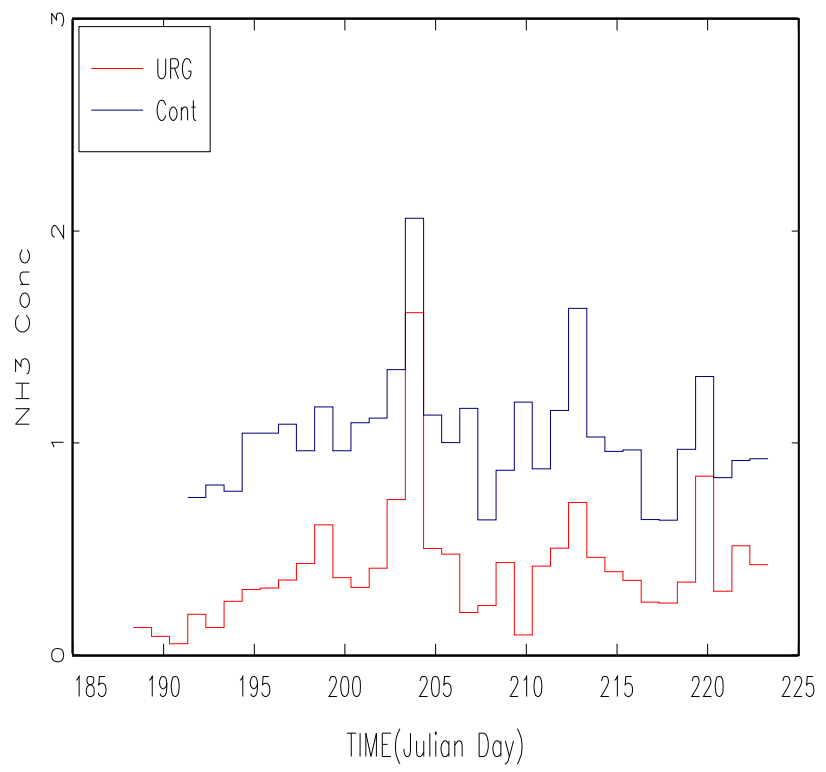
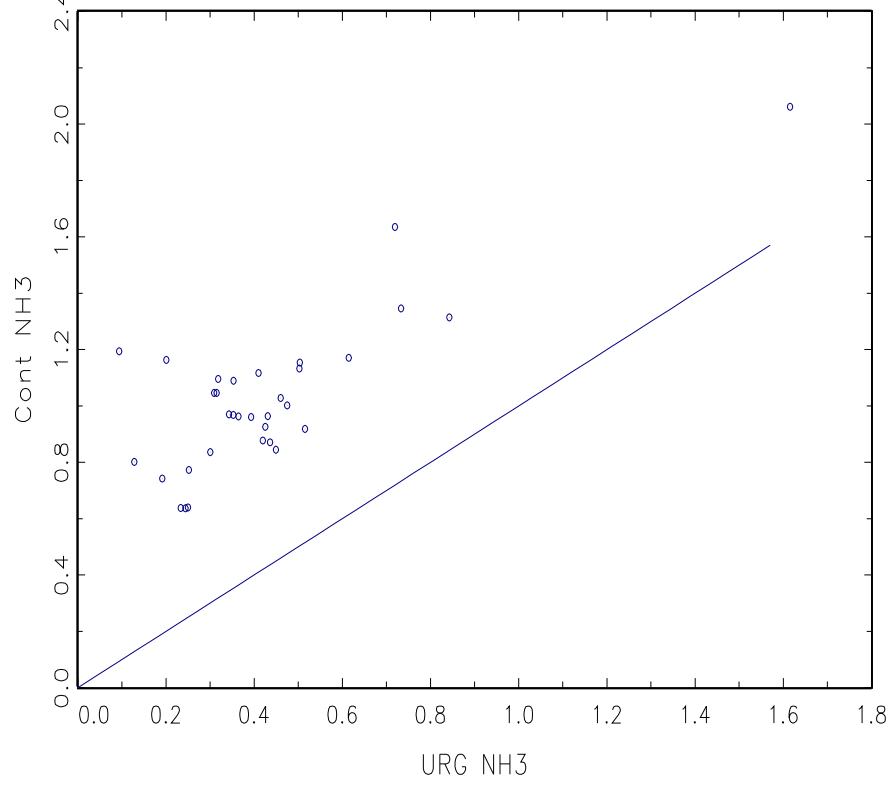


# Summer pils and URG NH4

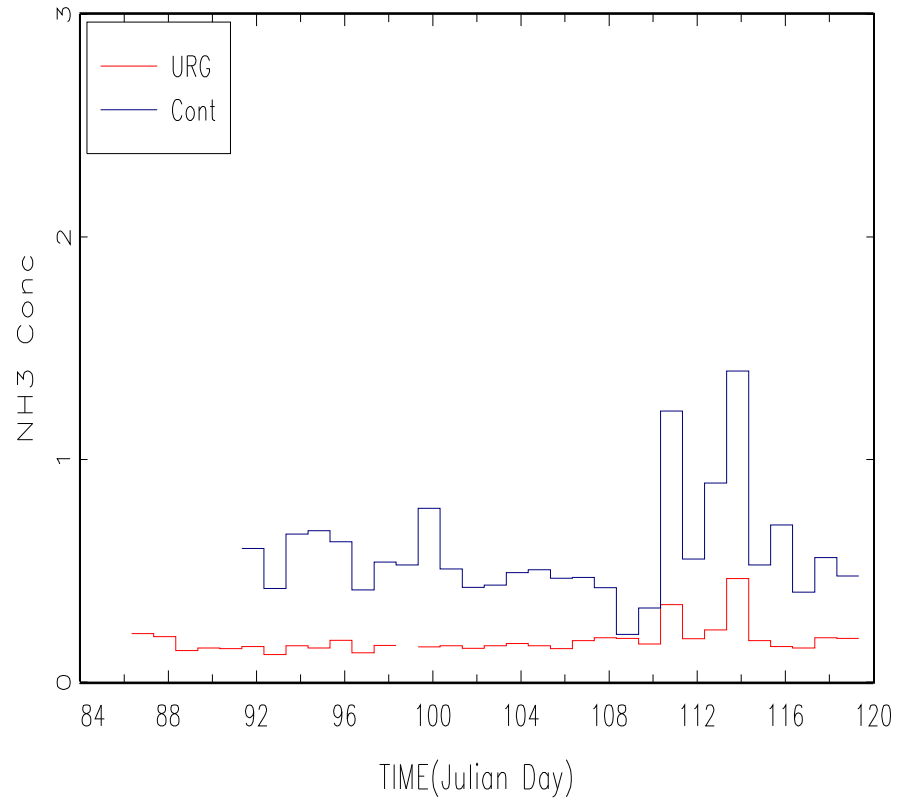
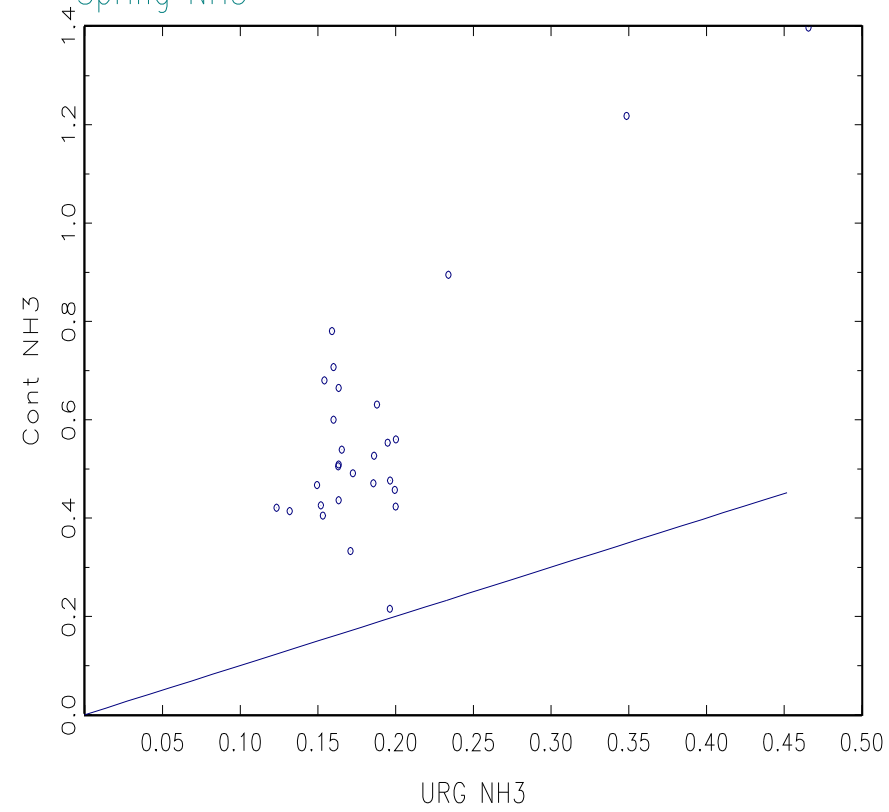




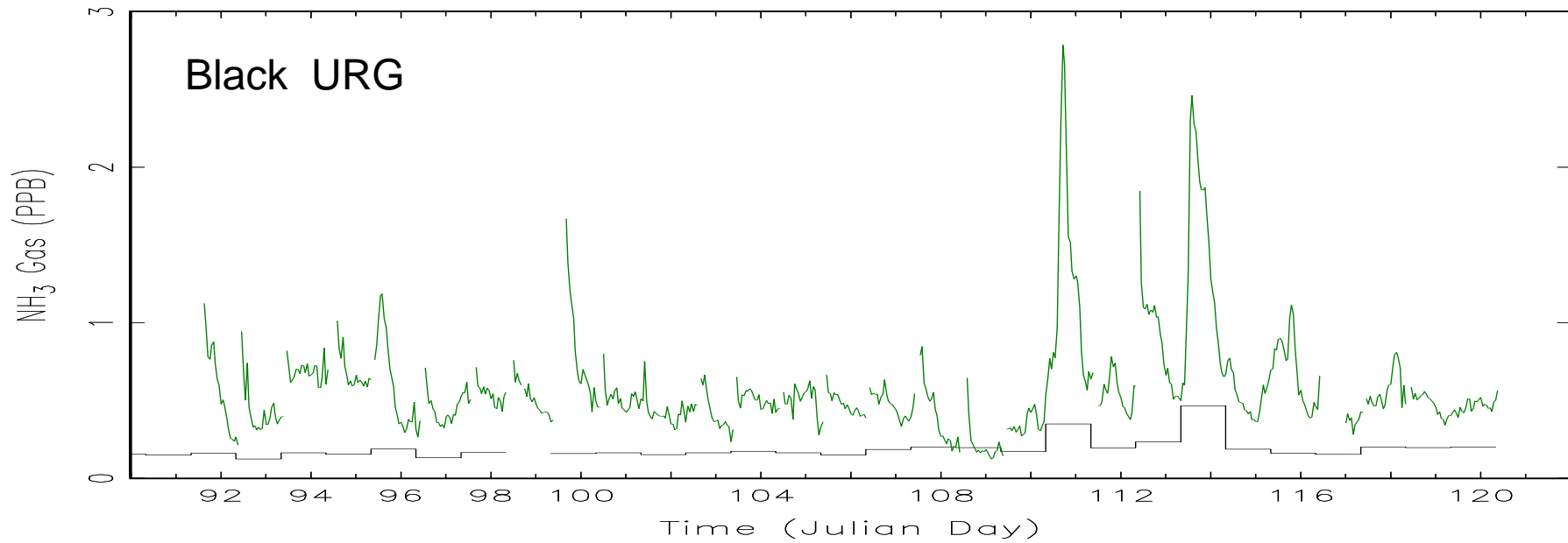
Summer NH3



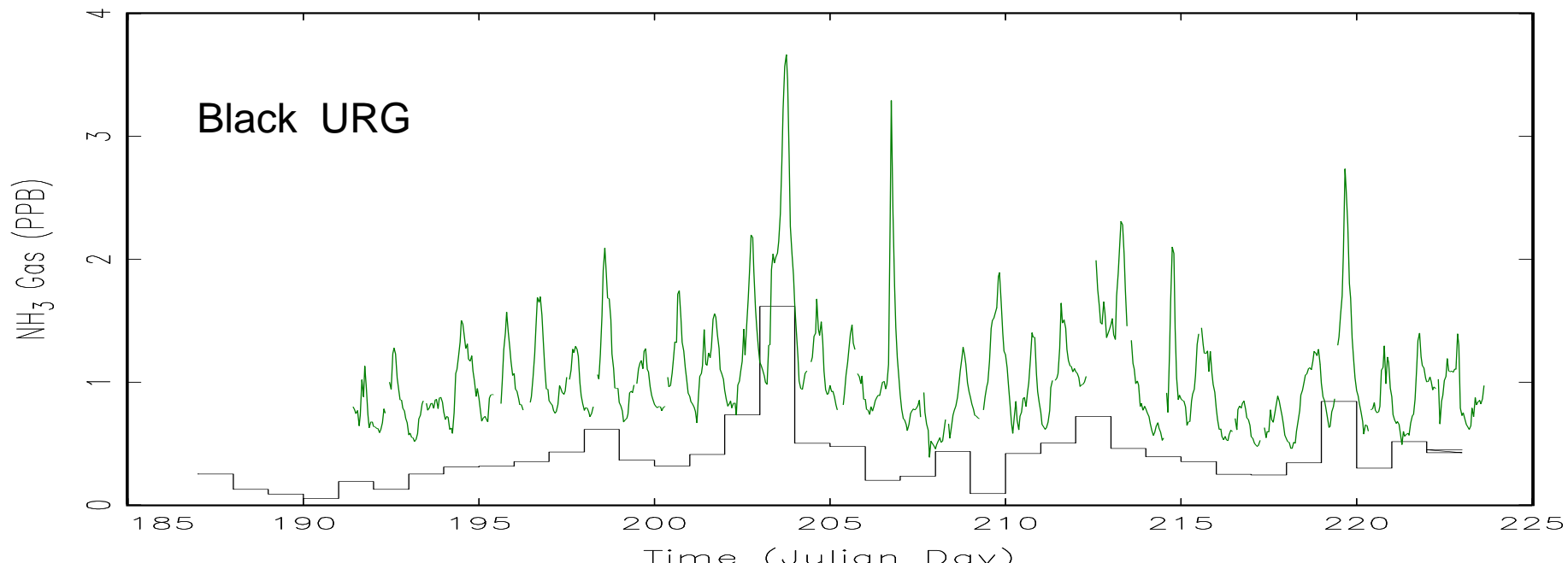
Spring NH3

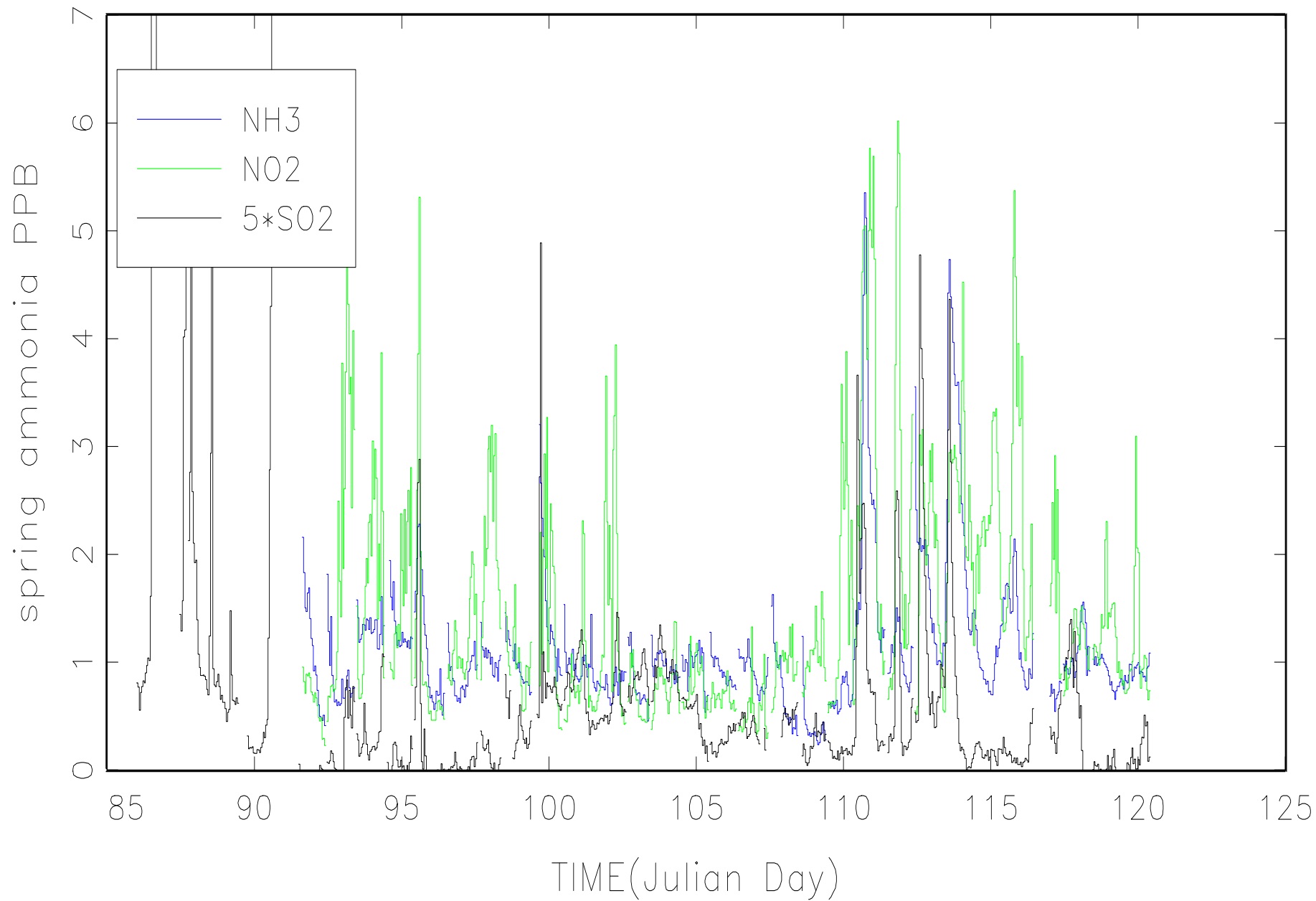


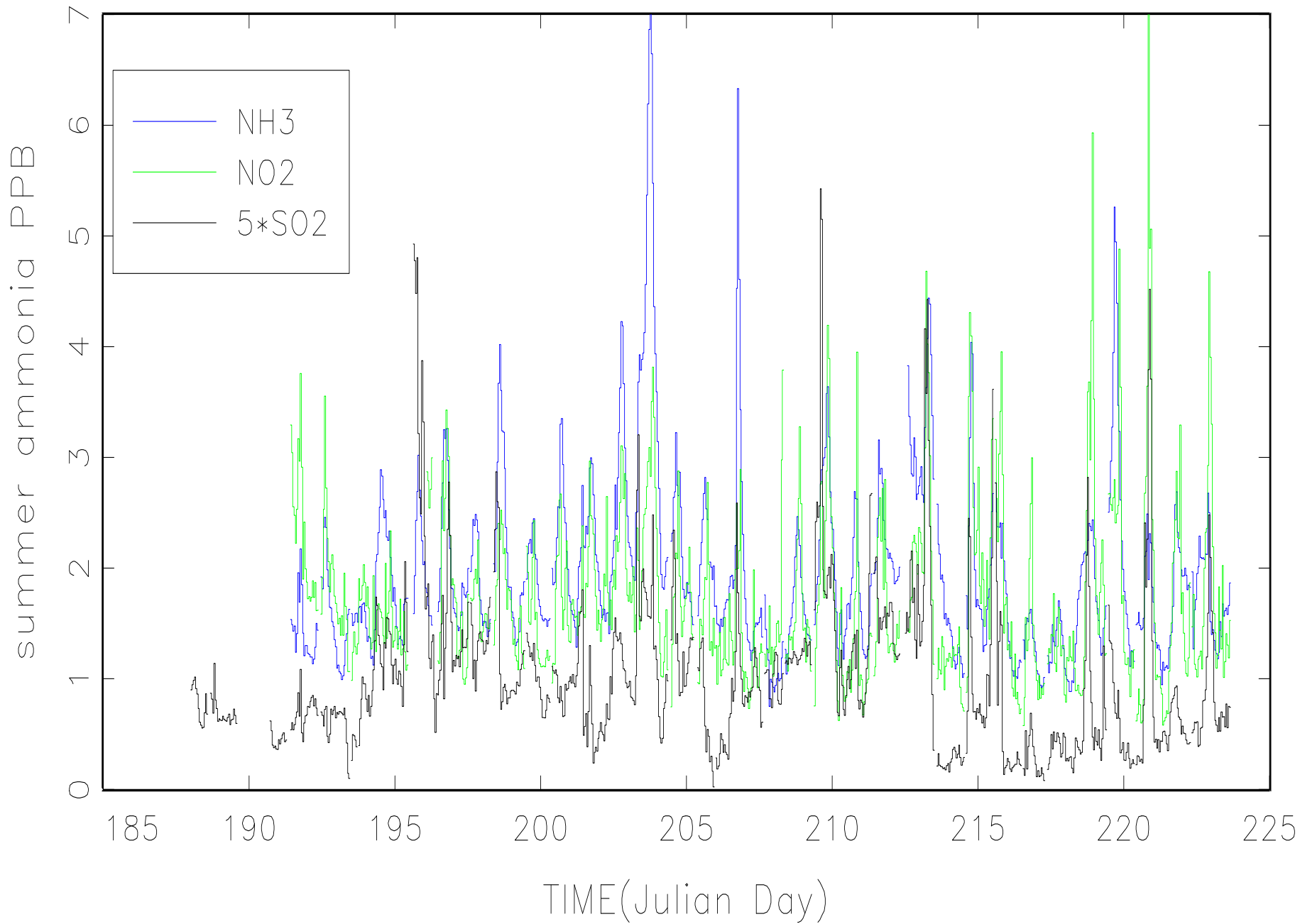
# Spring NH<sub>3</sub> data



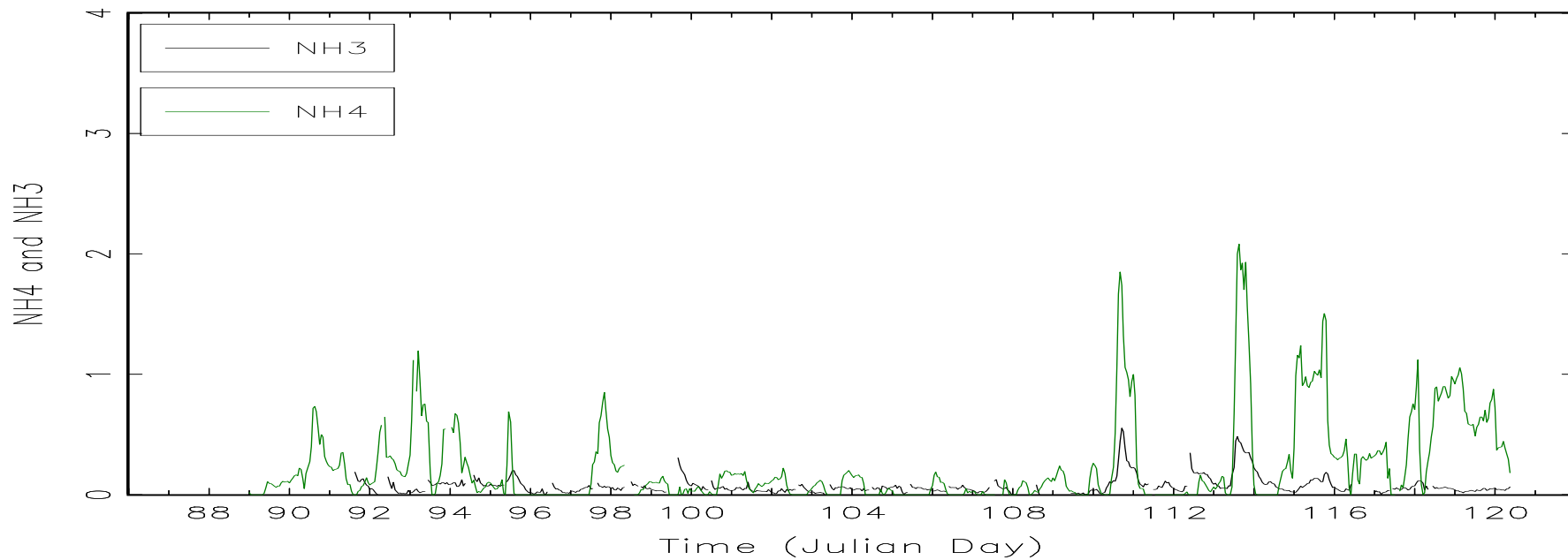
# Summer NH<sub>3</sub> data



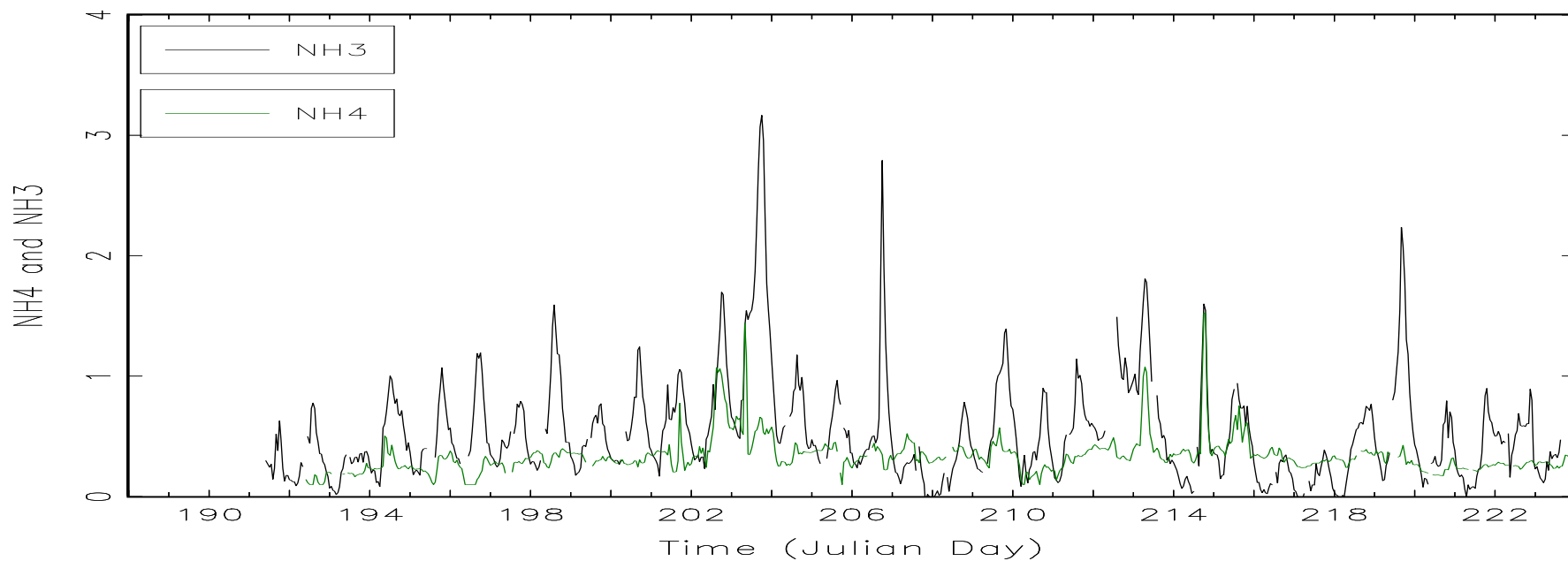




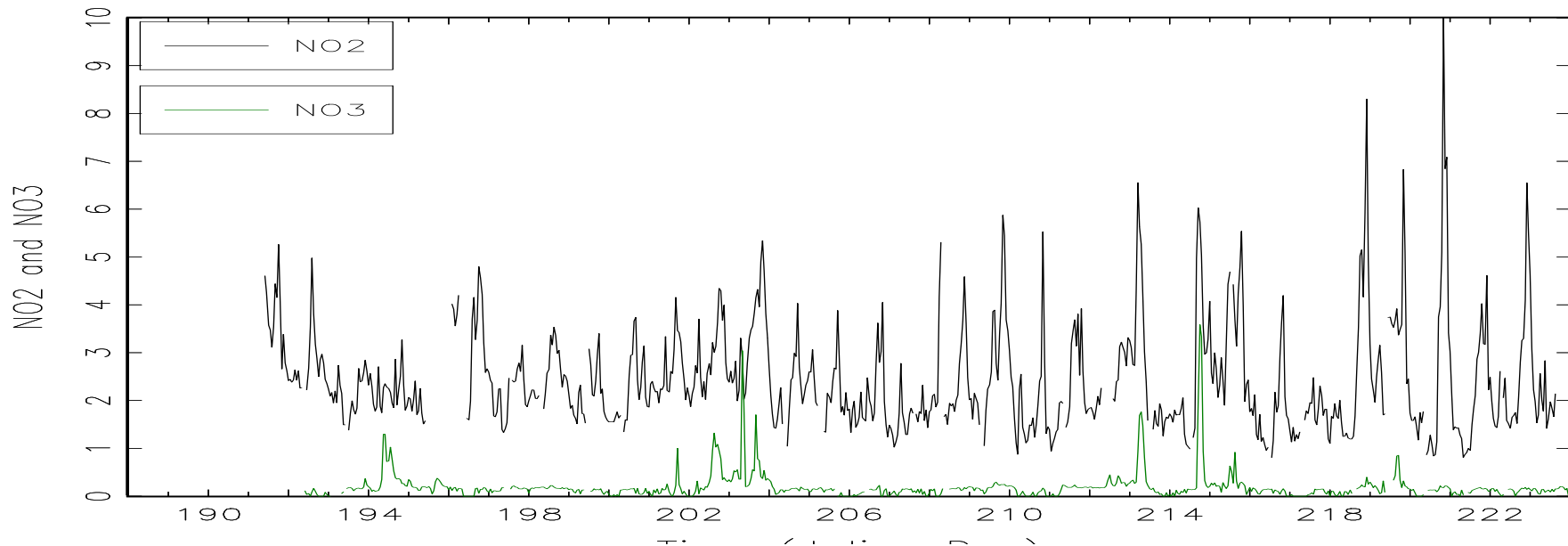
### Spring



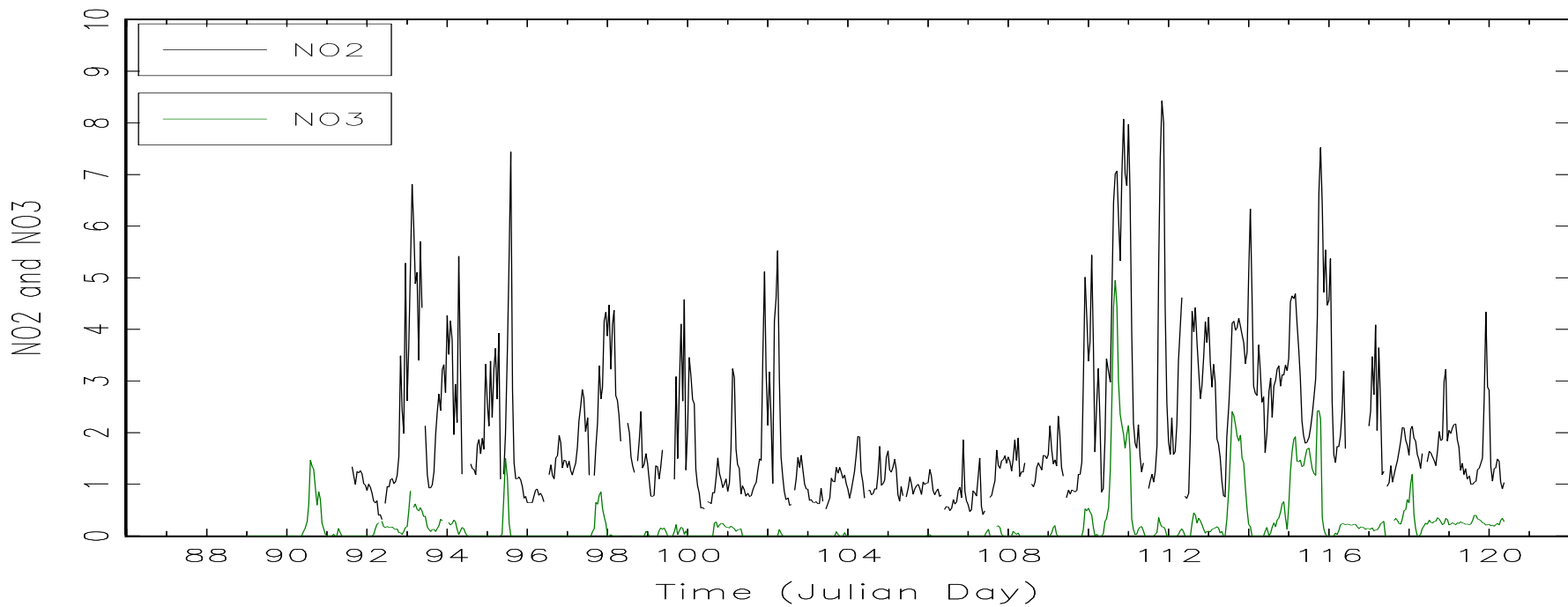
### Summer



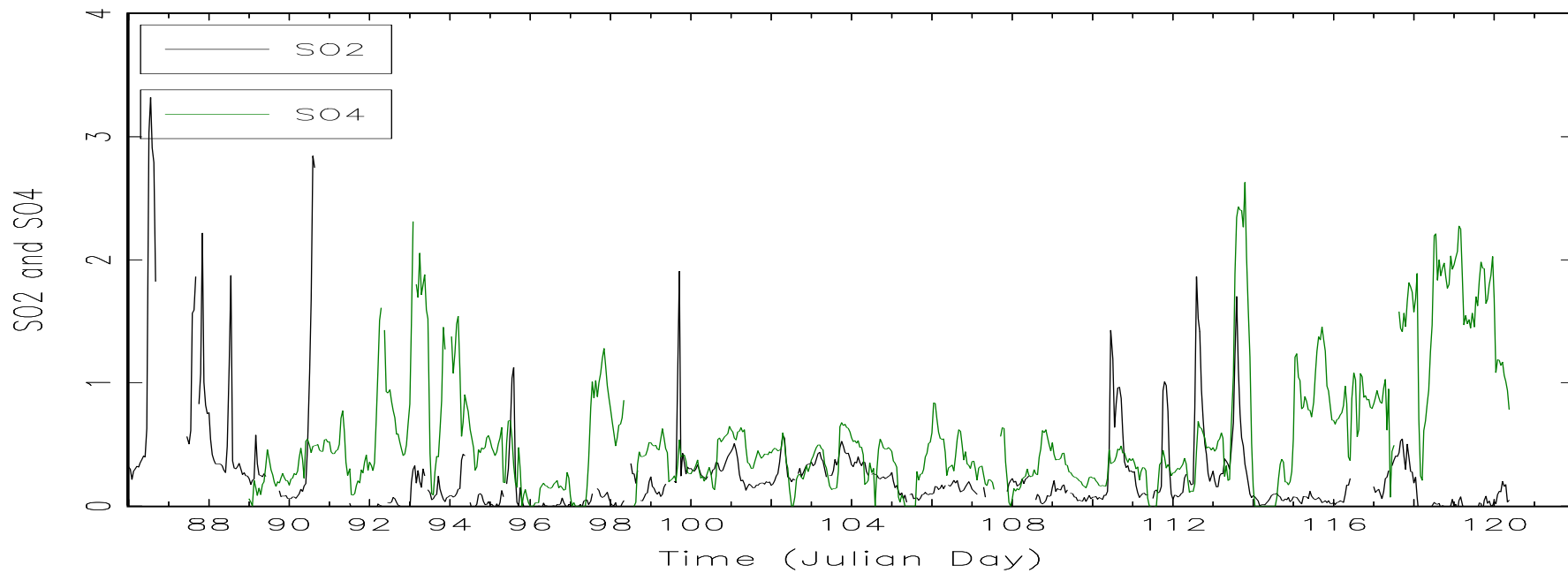
Summer



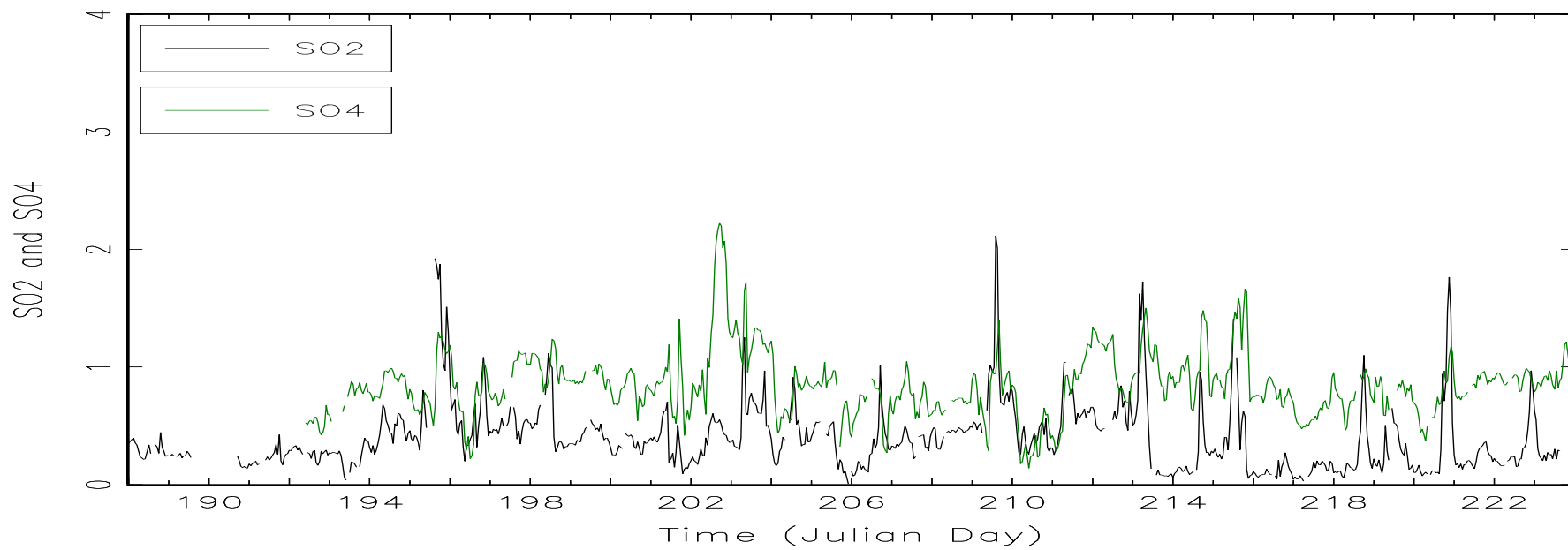
Spring



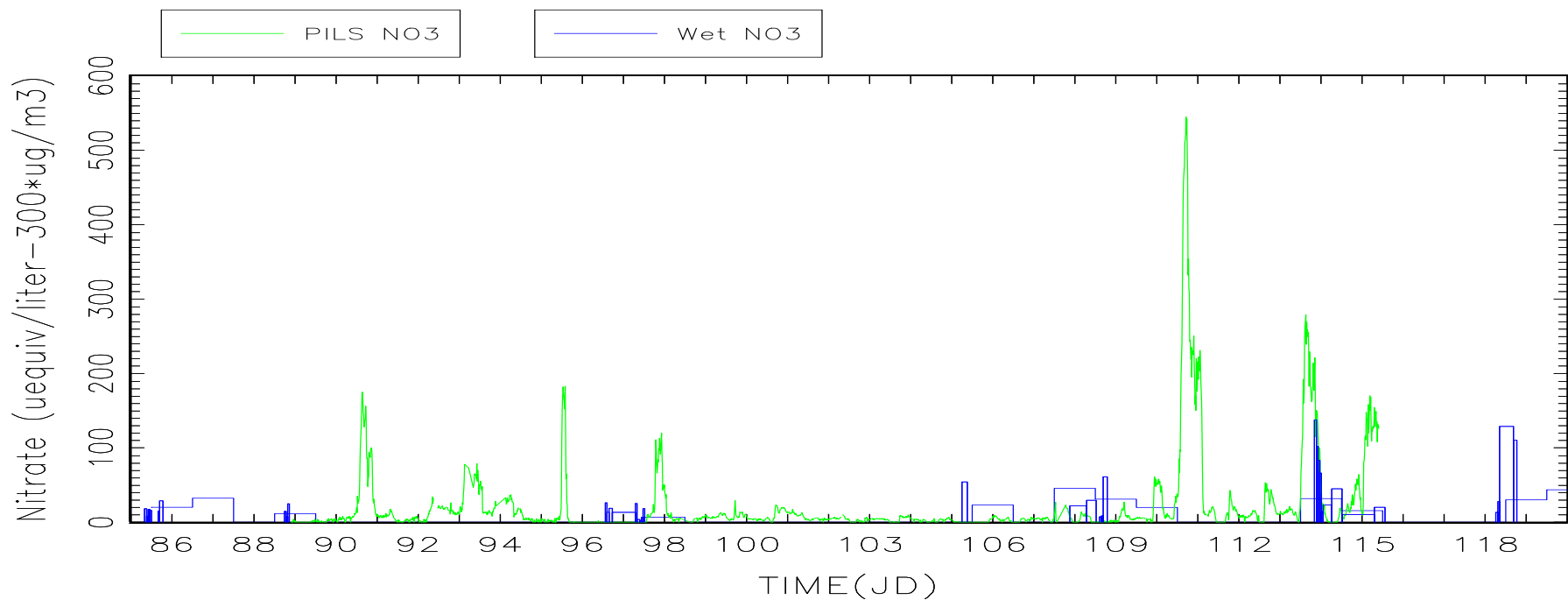
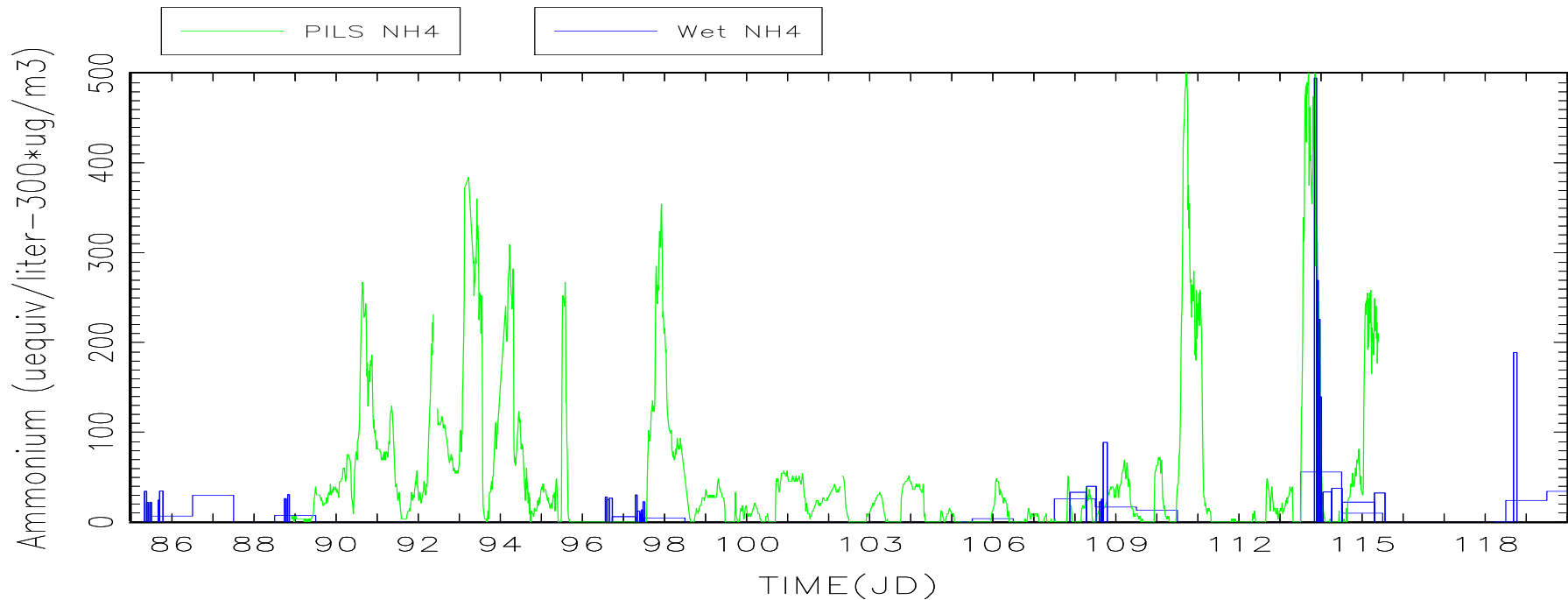
### Spring

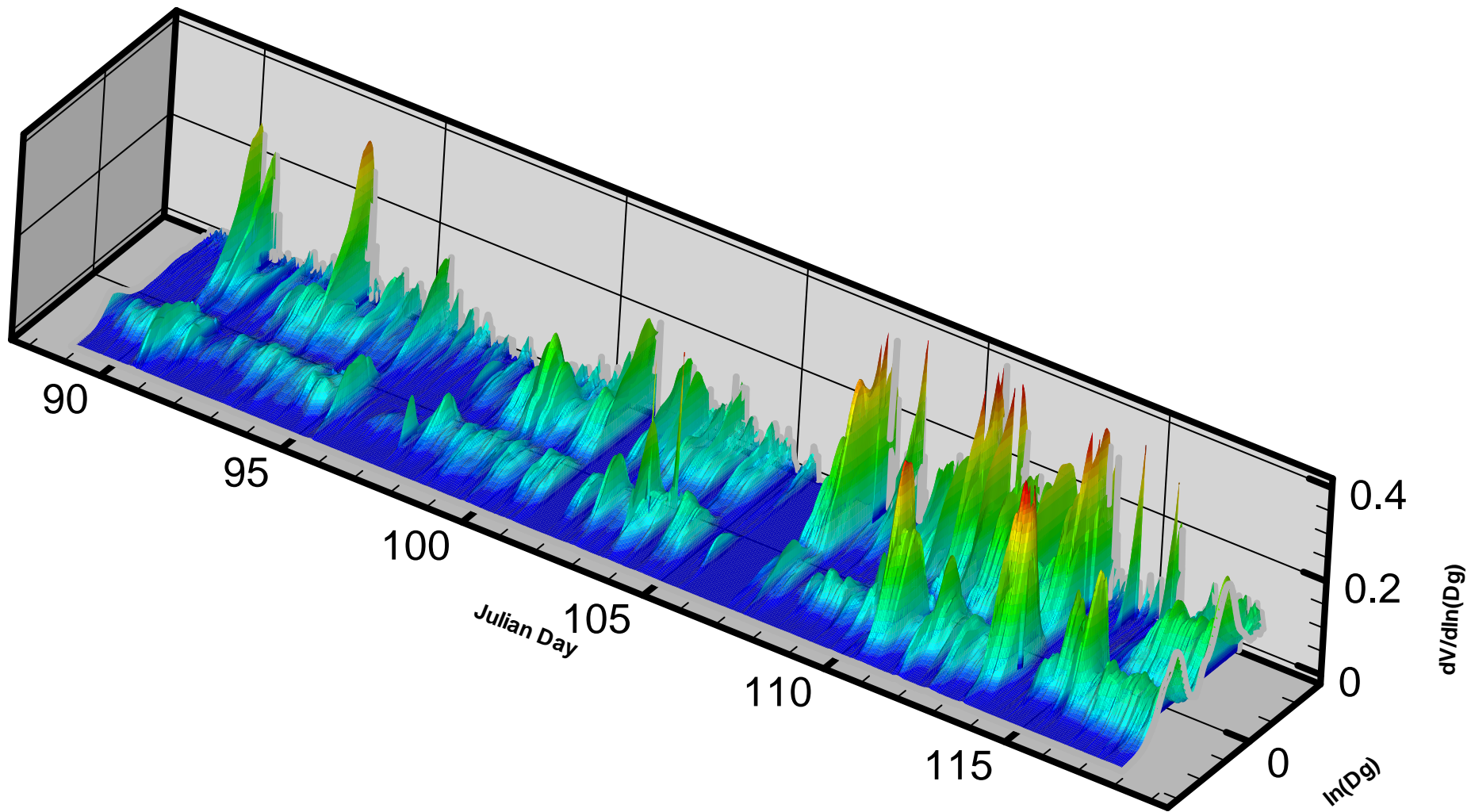


### Summer

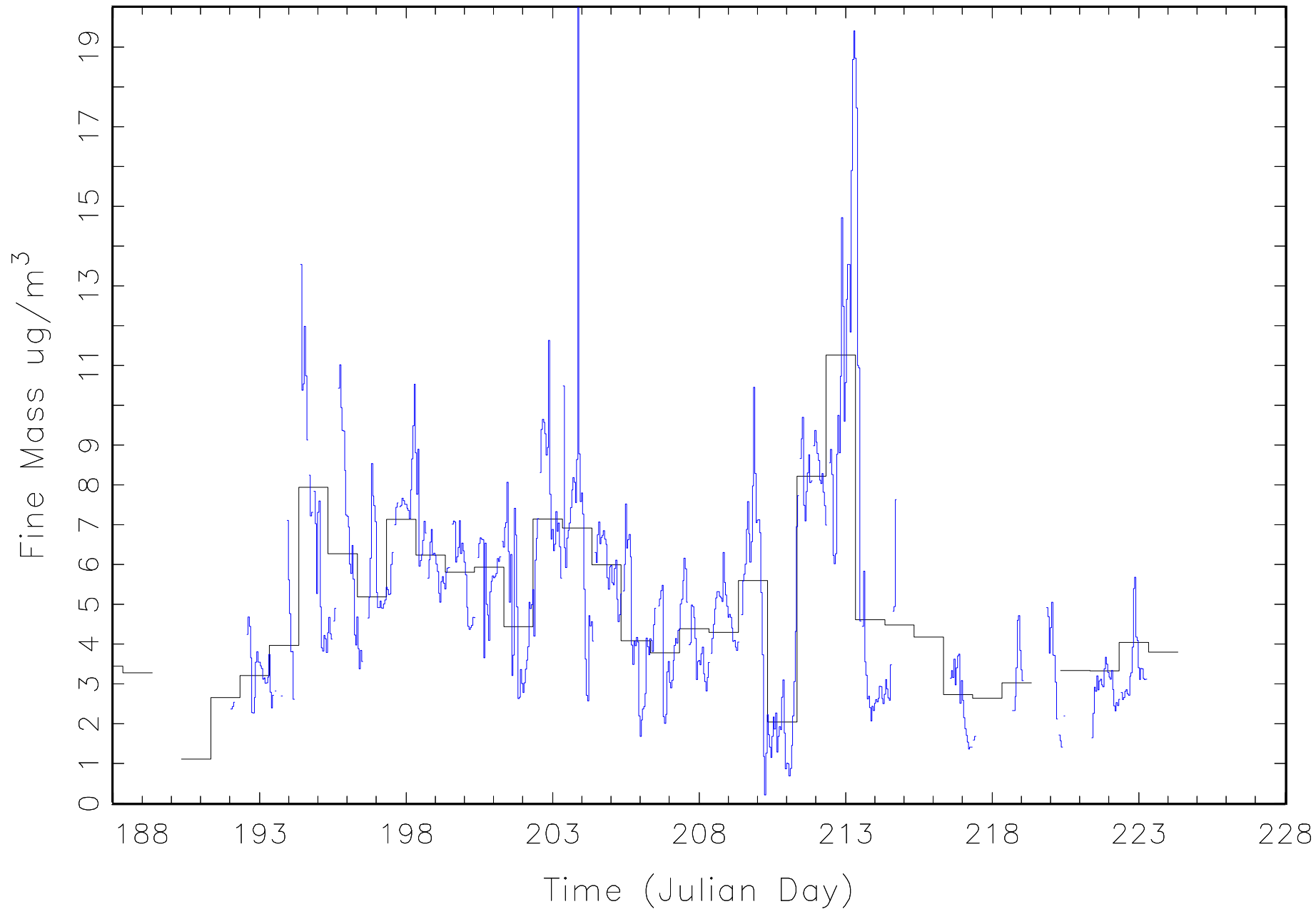




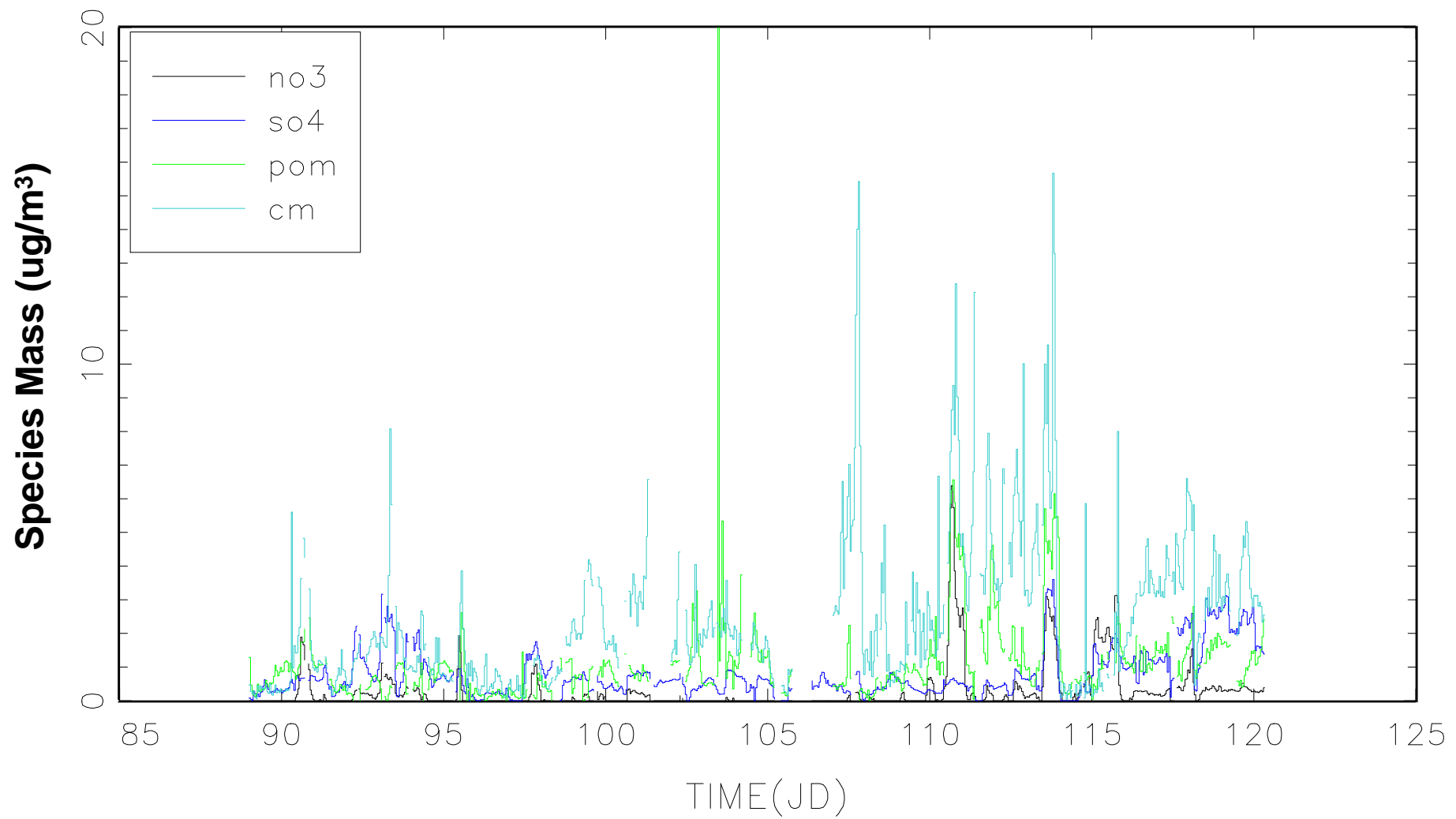




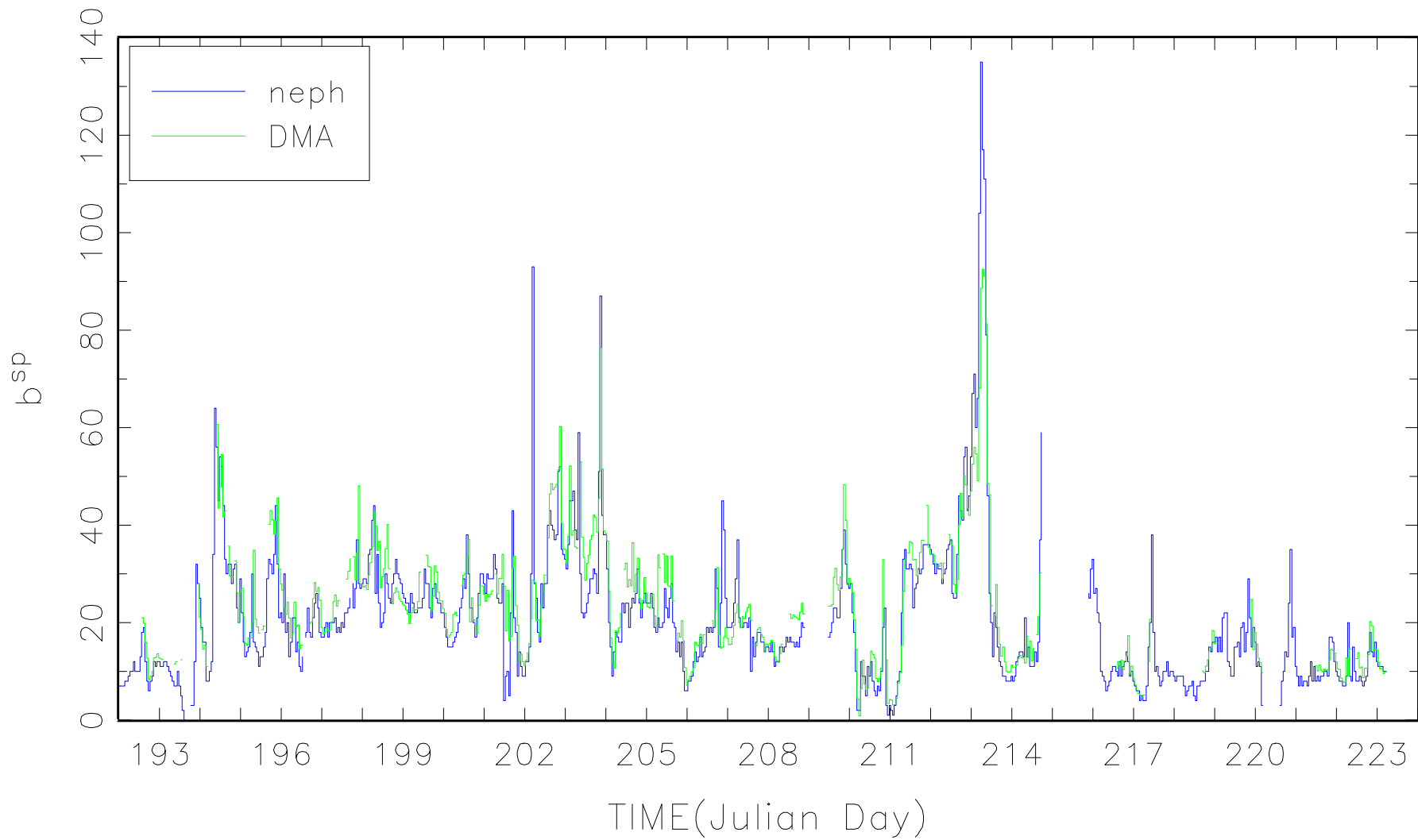
# IMPROVE and DMA (SUMMER)



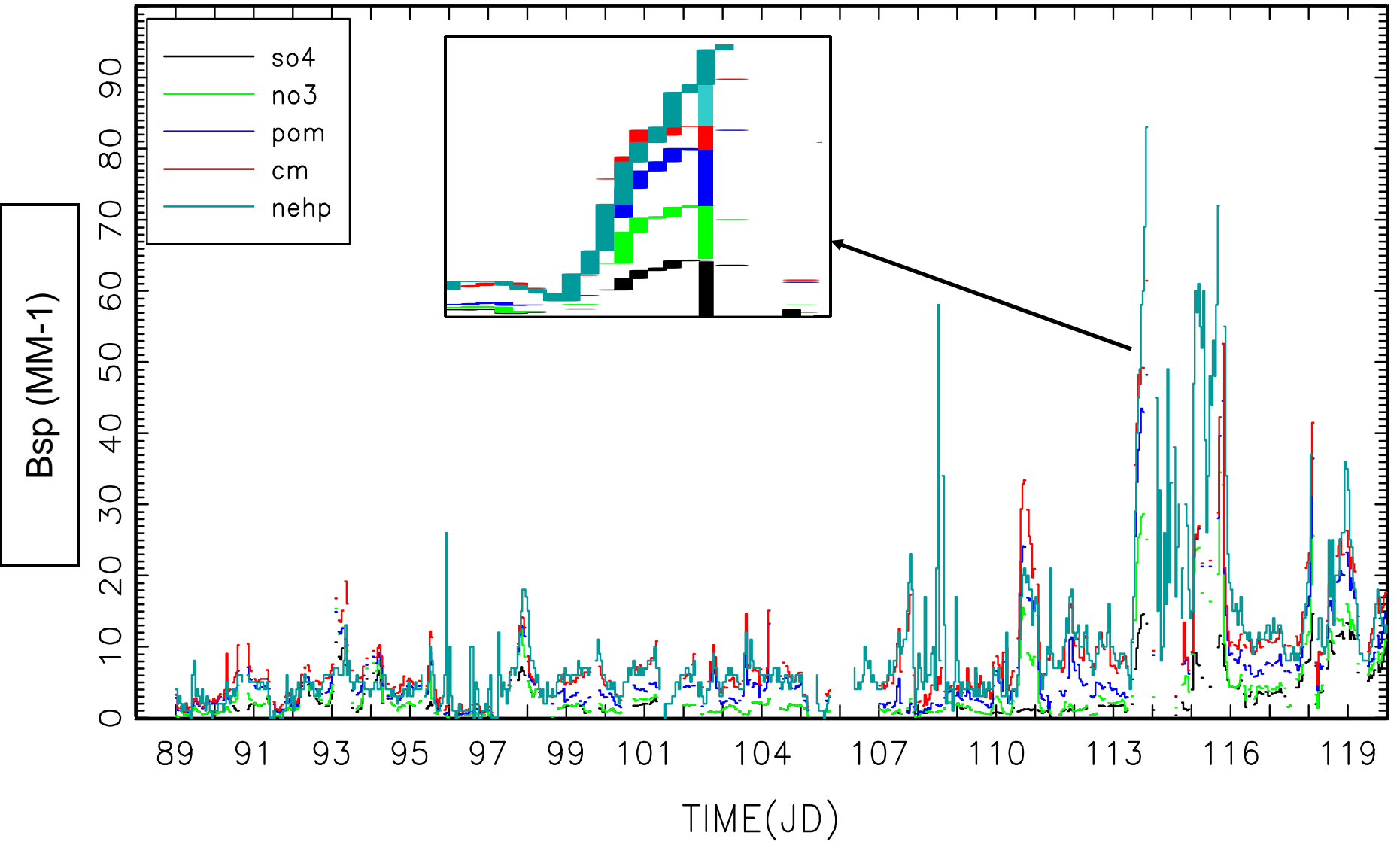
SPRING



# SUMMER

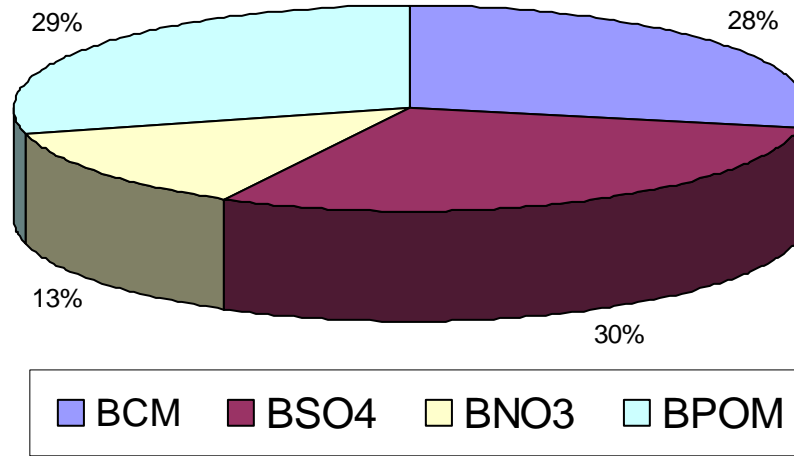


# SPRING



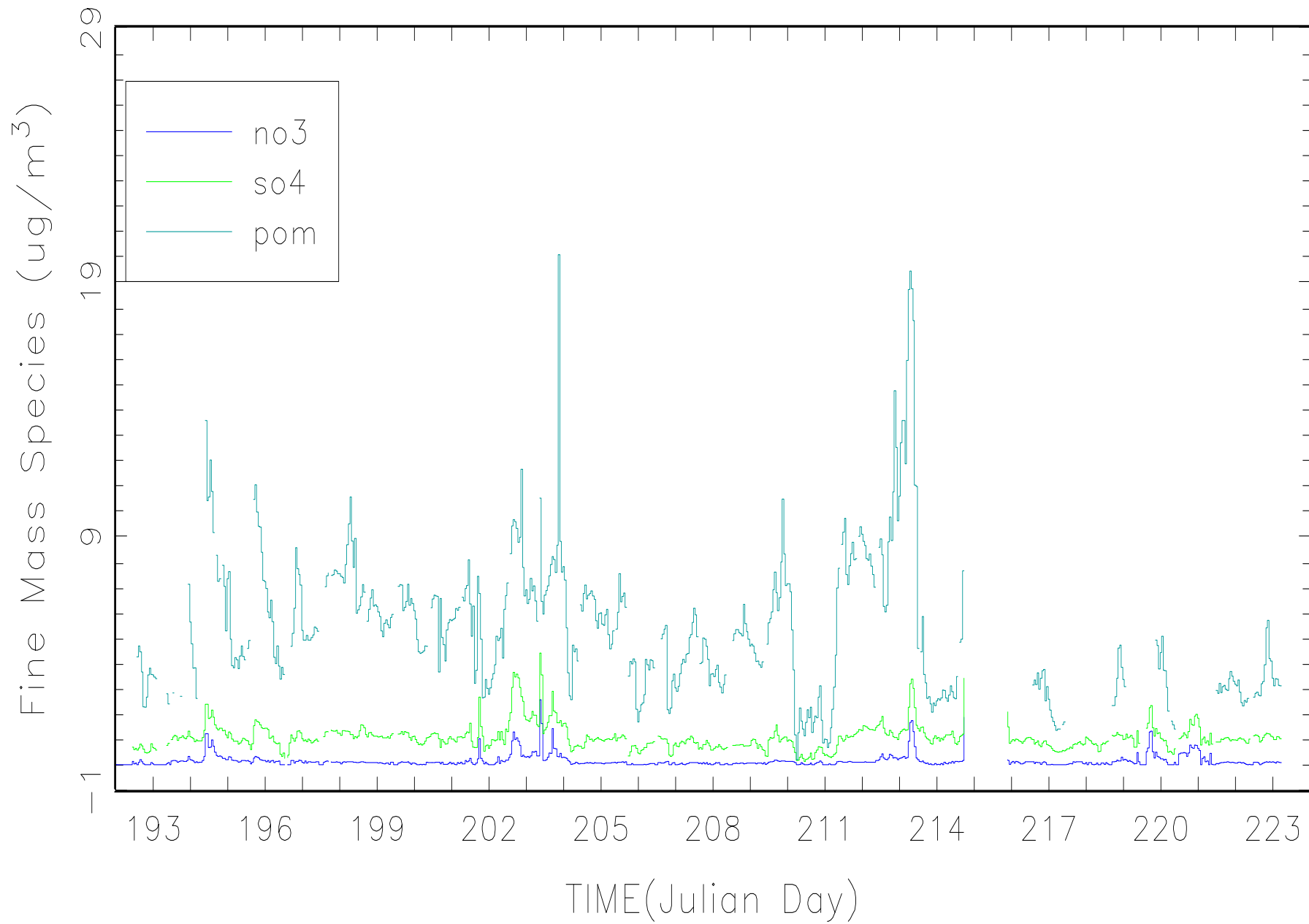
# SPRING

Scattering Budget (7.28 MM-1)



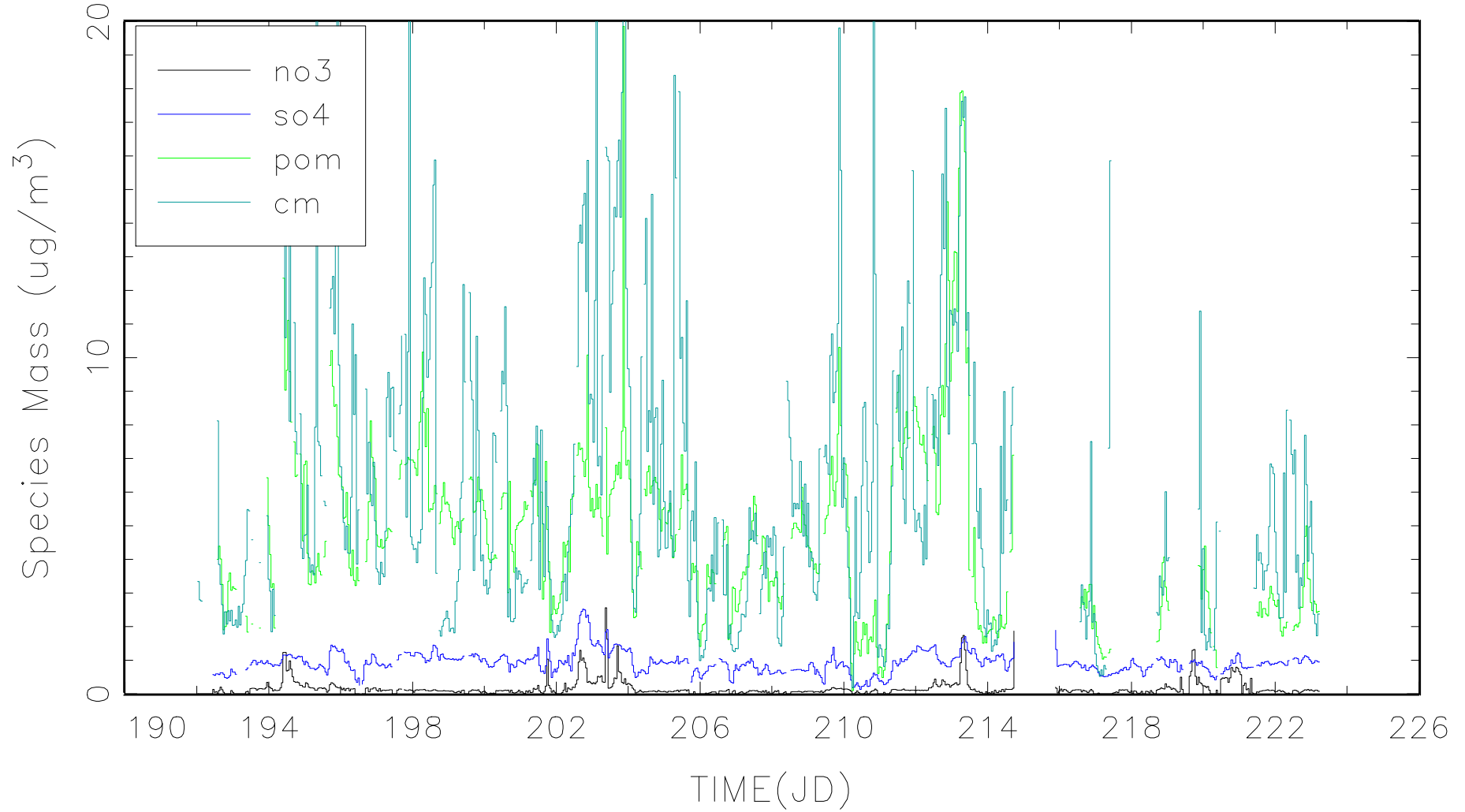
Variable	Mean	Std_Dev	Variance	Minimum	Maximum	Valid
EFF	2.26	0.45	0.20	1.28	3.84	572
BNEPH	9.30	10.64	113.30	-1.00	83.00	737
BDMAF	4.78	6.07	36.87	0.23	47.35	572
BCM	2.42	2.23	4.99	0.04	15.67	635
BTOT	7.28	7.18	51.54	0.55	63.02	572
BSO4	2.58	2.83	7.99	0.07	16.81	572
BNO3	1.14	2.69	7.23	0.00	16.55	572
BPOM	2.49	3.71	13.74	-1.45	68.54	572

# SUMMER

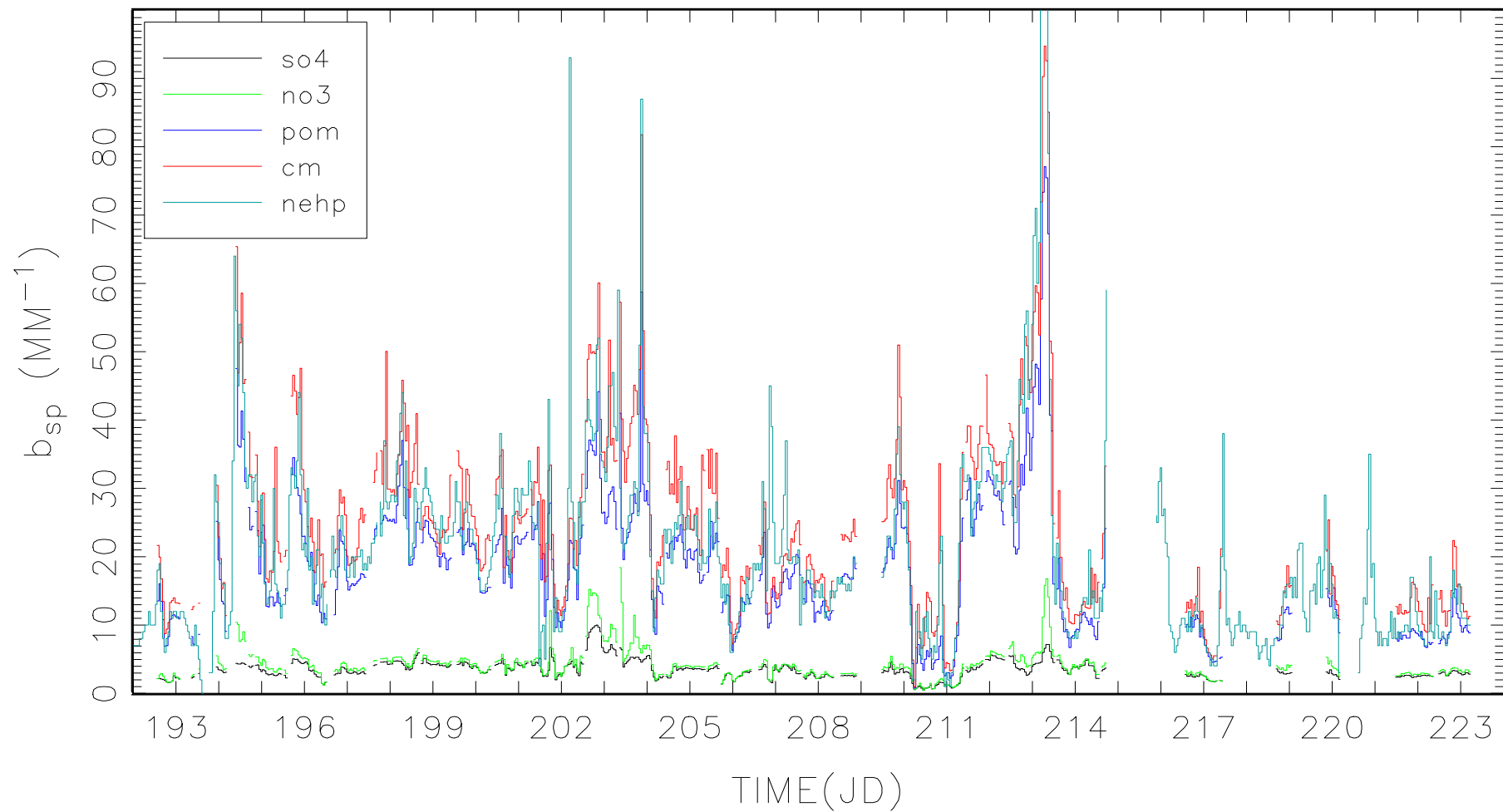




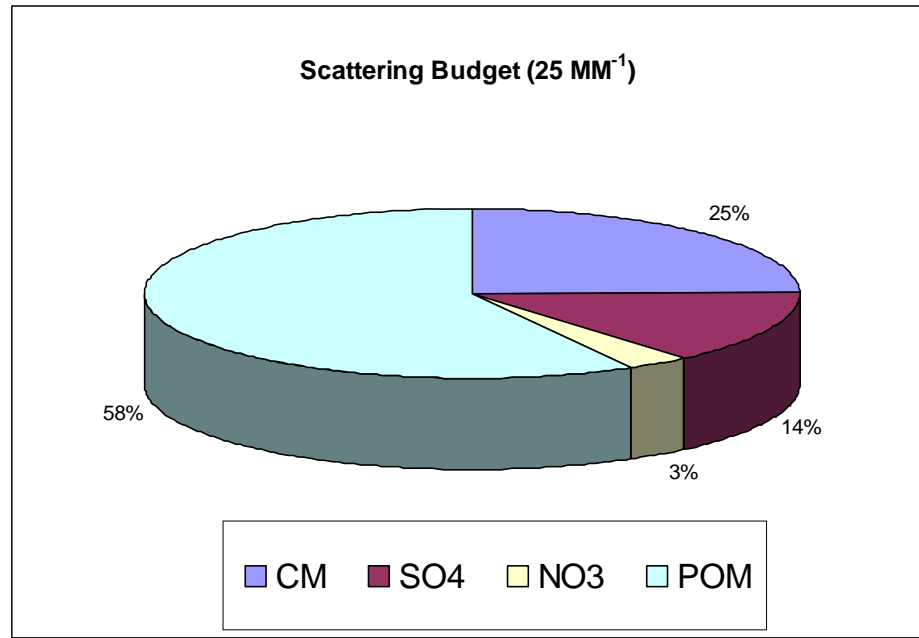
SUMMER



# SUMMER



# SUMMER

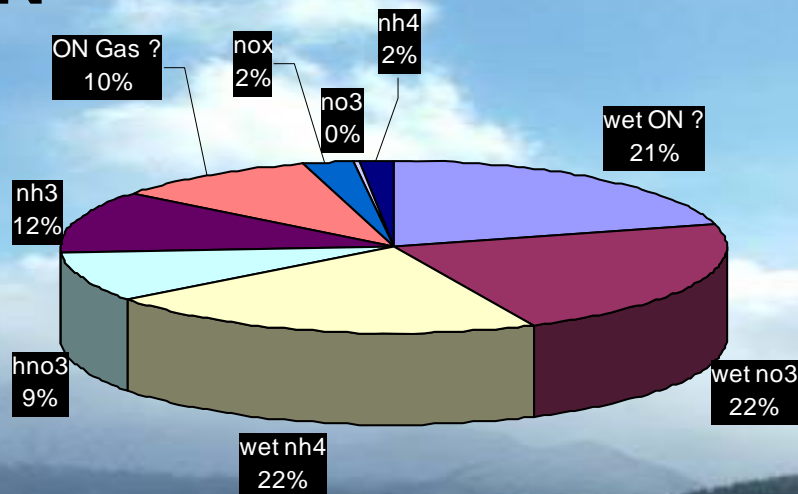


Variable	Mean	Std_Dev	Variance	Minimum	Maximum	Valid
EFFS	2.93	0.29	0.08	2.11	3.66	532
BABS	0.01	0.01	0.00	0.00	0.12	532
BNEPH	20.59	14.02	196.65	0.00	135.00	723
BDMAF	17.45	9.74	94.93	0.67	74.89	532
BCM	6.14	4.37	19.13	0.19	26.72	574
BTOT	23.71	12.86	165.31	0.86	92.52	532
BSO4	3.50	1.39	1.92	0.44	10.02	532
BNO3	0.75	1.21	1.47	0.00	11.78	532
BPOM	14.33	8.56	73.27	0.22	62.20	532

# PRELIMINARY DEPOSITION RESULTS

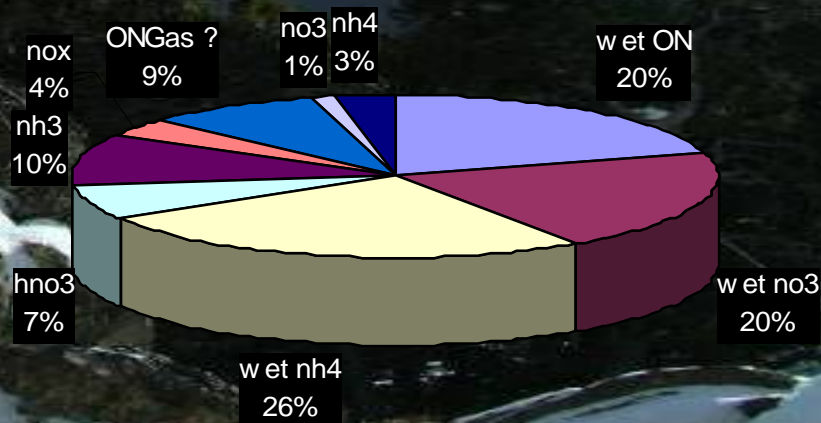
## SUMMER

Total Dep = 6228 ug/m<sup>2</sup>



## SPRING

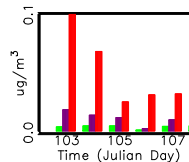
Total Dep=3326 ug/m<sup>2</sup>



- Total N deposition was about twice (2) as high during the summer vs spring.
- About 45% of N deposition is not being measured in the current monitoring programs (NAPD & CASTNET).
- Deposition of N is about 2/3 wet (rain and snow) and 1/3 dry (particles and gases).
- Organic N may be about 30% of total deposition and is not currently being measured.

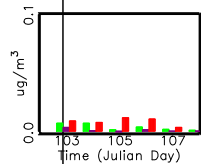
# SPRING

Brush

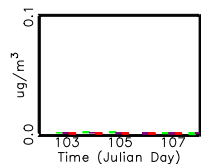


NH3 is divide by 10

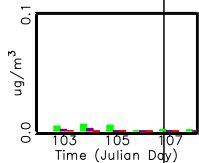
Dinasour



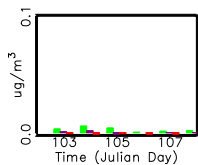
Timber Creek



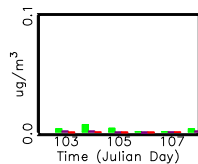
Gore Pass



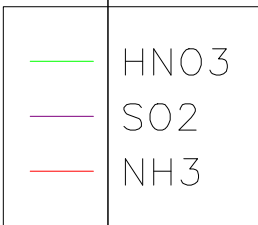
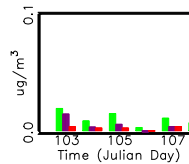
Beaver Meadows



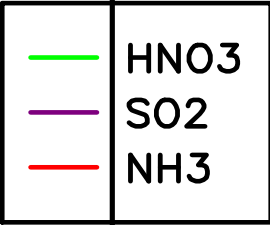
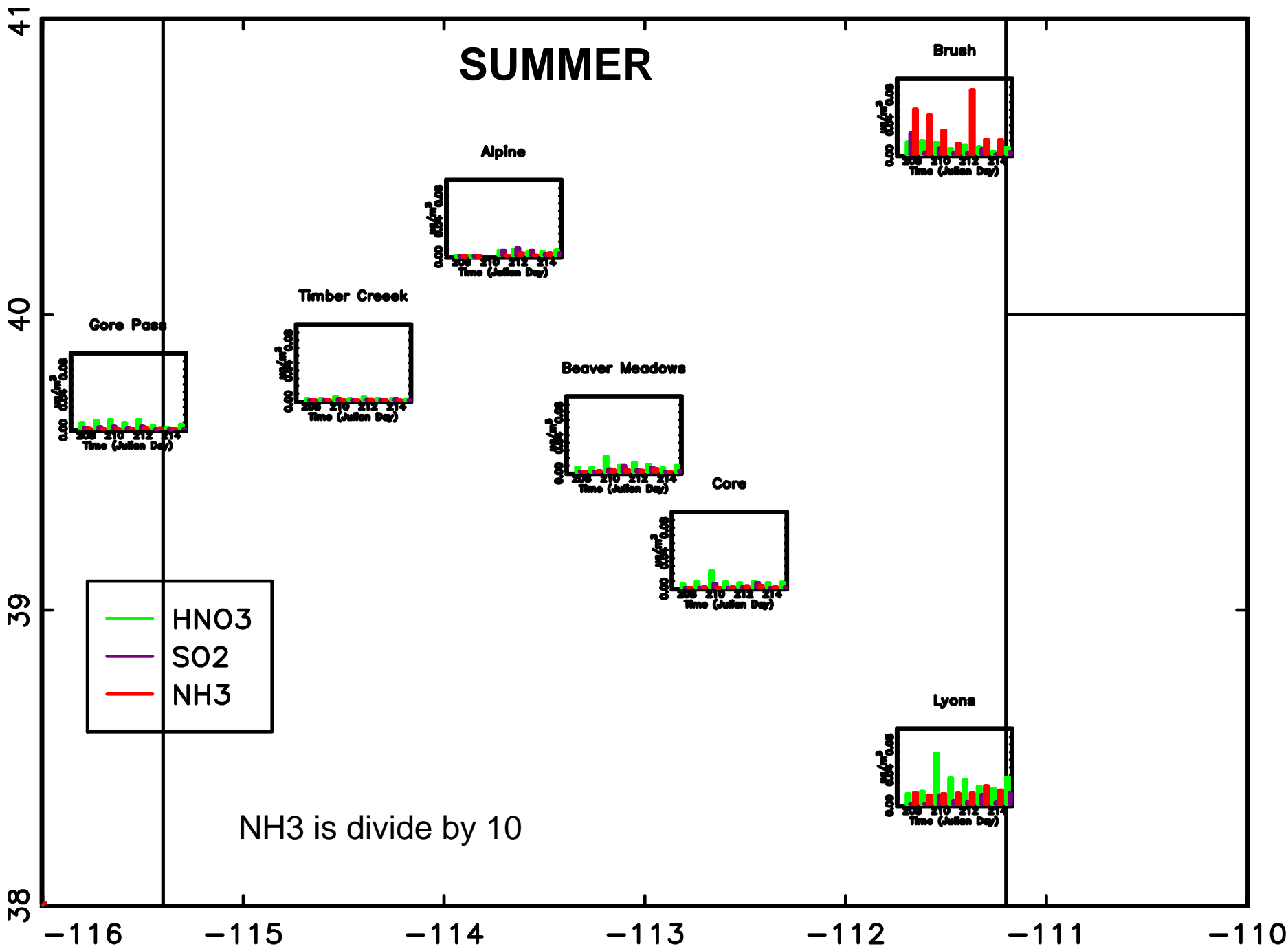
Core



Lyons



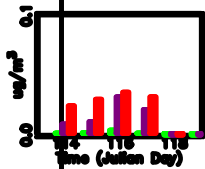
# SUMMER



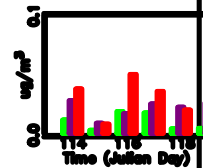
NH3 is divide by 10

# SPRING

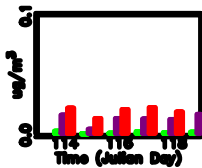
Dinosaur



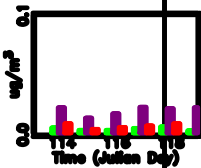
Brush



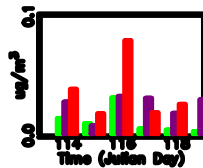
Timber Creek



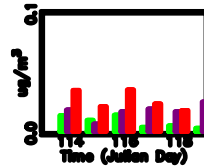
Gore Pass



Beaver Meadows



Core



NO3



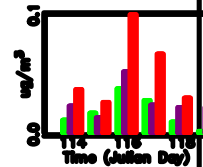
SO4



NH4



Lyons



41

40

39

38

-116

-115

-114

-113

-112

-111

-110

# Spring pils and urg N03

