Trace Metal Biogeochemistry Laboratory TMBL

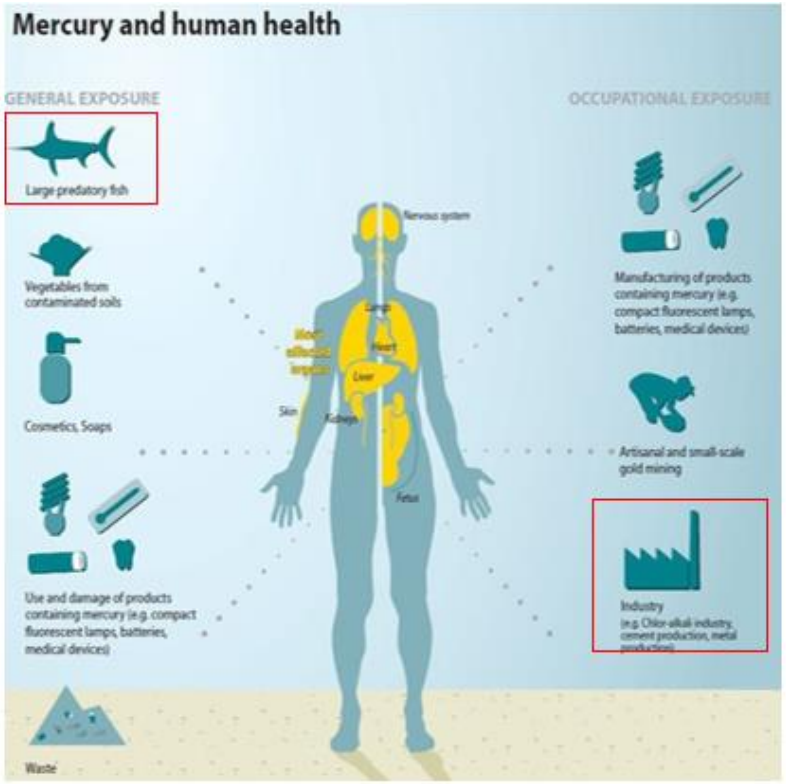
광주과학기술원 Gwangju Institute of Science and Technology

2019 APMMN meeting

National mercury monitoring activities in Korea

Sangwoo Eom and Seunghee Han
School of Environmental Sciences and Engineering
Gwangju Institute of Science and Technology (GIST)
Gwangju, Korea

1. Introduction

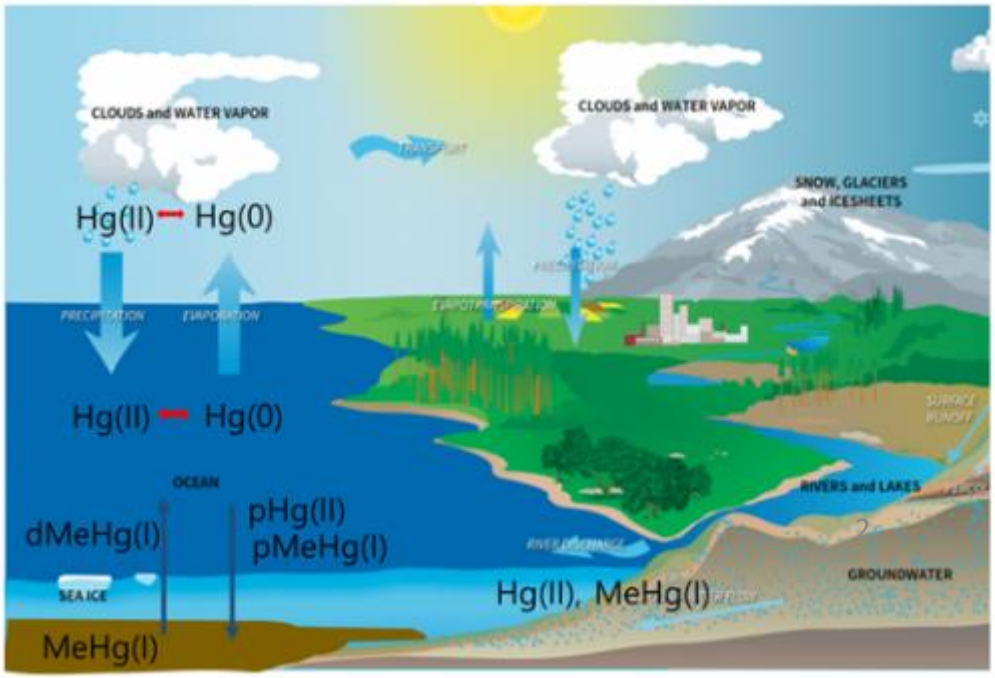


Zero-valent mercury, Hg(0)

- <0.01% bioavailability after ingestion
- After inhalation it easily crosses blood-brain barrier
- Disorder of central nervous system
- Nervousness, erethism

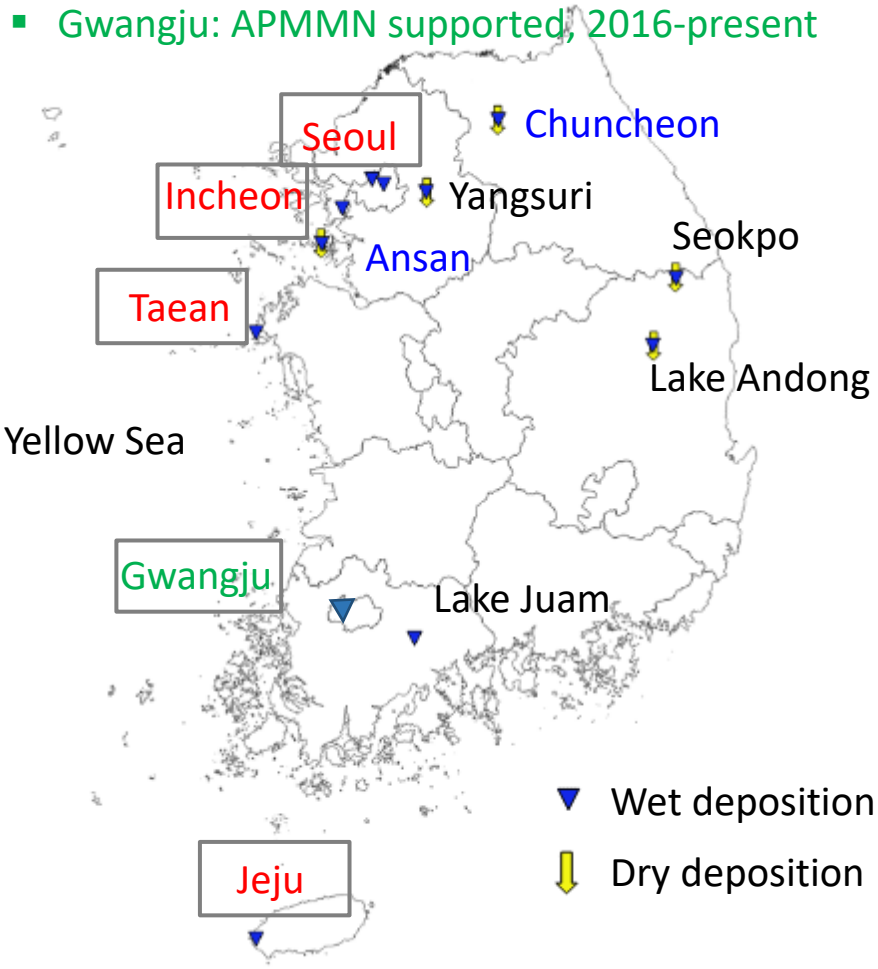
Divalent mercury, Hg(II)

- 7–15% bioavailability after ingestion
- Kidney damage
- Renal tubule damage
- Nephritis



2. National monitoring network for wet deposition

- Jeju, Taean, Incheon, Seoul: national monitoring sites, weekly sampling, 2015-present
- Andong, Seokpo: event sampling, 2010-2015
- Ansan: event sampling, 2006-2007
- Chuncheon: event sampling, 2015-2017
- Gwangju: APMMN supported, 2016-present



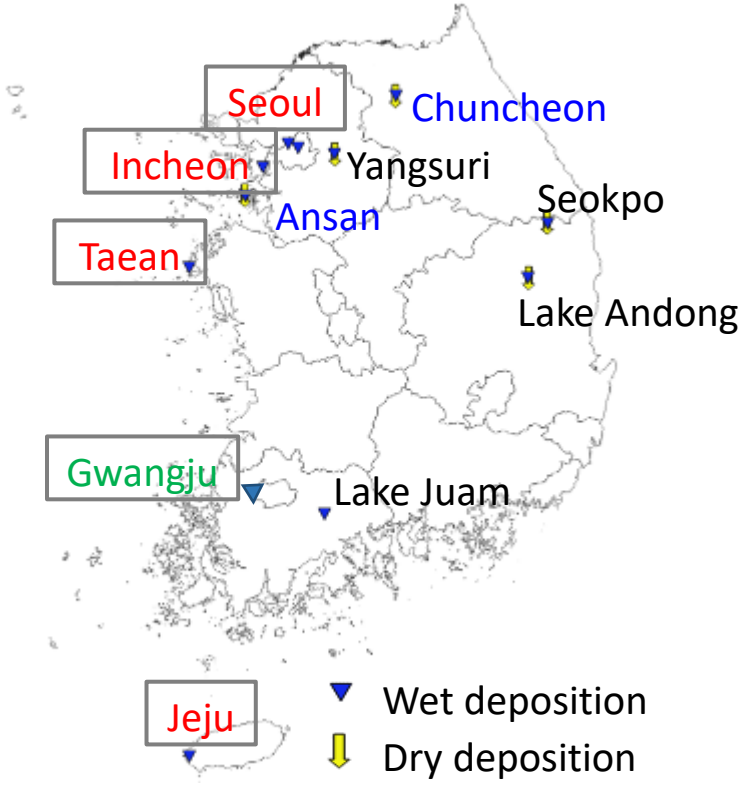
Ansan

Gwangju

2. National monitoring network for wet deposition

- Demographic information

Site	Population
Seoul	9,757,144
Incheon	2,957,024
Taean	63,064
Jeju	669,771
Gwangju	1,459,024



- Annual precipitation depth (unit: mm)

Site	2014	2015	2016	2017	2018	Average
Seoul	809	792	992	1233	1284	1022
Incheon	788	652	864	1029	1134	894
Taean	720	536	748	715	991	742
Jeju	1272	1546	1293	861	1346	1264
Gwangju	1290	1050	1482	937	1428	1237
Korea	1174	949	1272	967.8	1387	1150

- Power plant scale (unit: MW)

Site	Gas	Coal	Coal gasification	Solar	Fuel cell	Petroleum	Wind	Bio	Hydro	Waste
Seoul	433			36	42			7	0.4	19
Incheon	8577	5080		68	75	36	49	71	13	3
Taean		6100	346	137		1			2	
Jeju				232		644	266	7	1	
Gwangju	115			148				2	2	1

2. National monitoring network for wet deposition

- Gwangju site has been operated from April 2016.
- THg is measured at the Dr Sheu's lab in Taiwan and MeHg at the GIST lab.

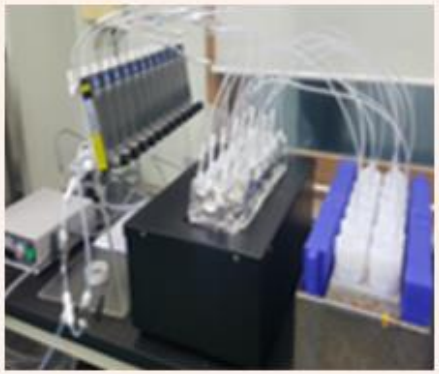
THg

BrCl oxidation

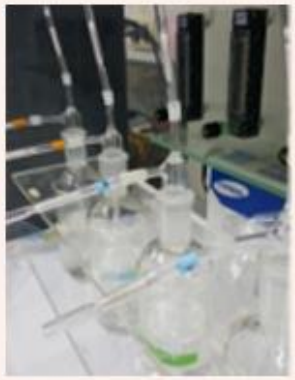
Reduction and sorption

CVAFS

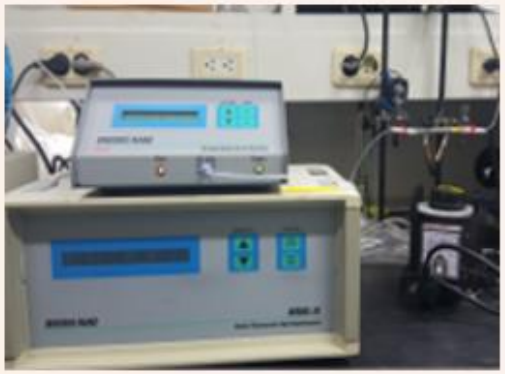
MeHg



Distillation



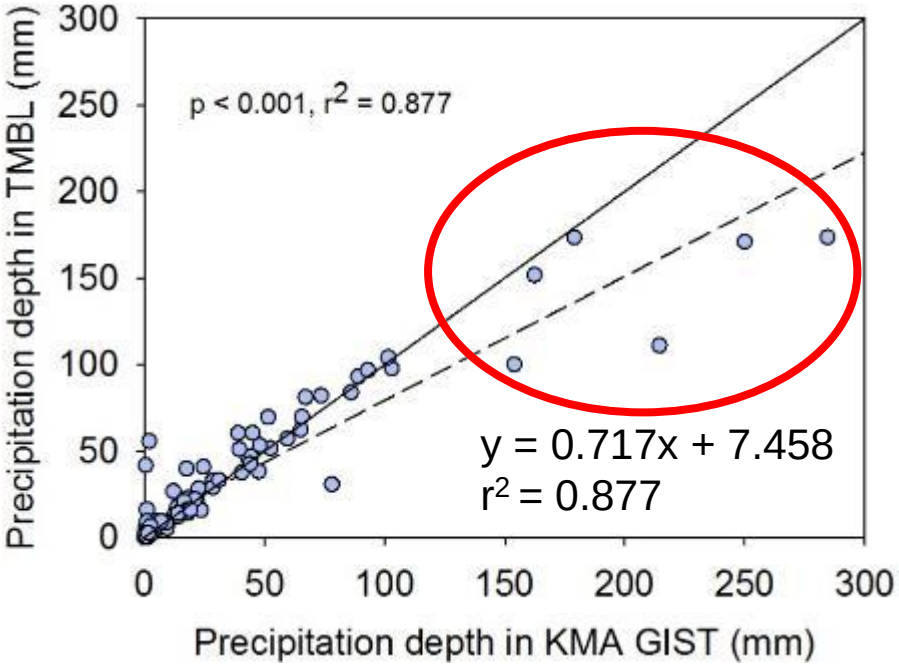
Ethylation and sorption



GC-CVAFS

2. National monitoring network for wet deposition

- The precipitation depth of Gwangju site was 28% lower than the KMA (Korea Meteorological Administration) data.



Duration: Apr 2016 – Mar 2019

Total: 108 samples

Enrichment Factor (EF) = $\frac{X/Na^{+}_{RW}}{X/Na^{+}_{SW}}$

(RW: rainwater) (SW: seawater)

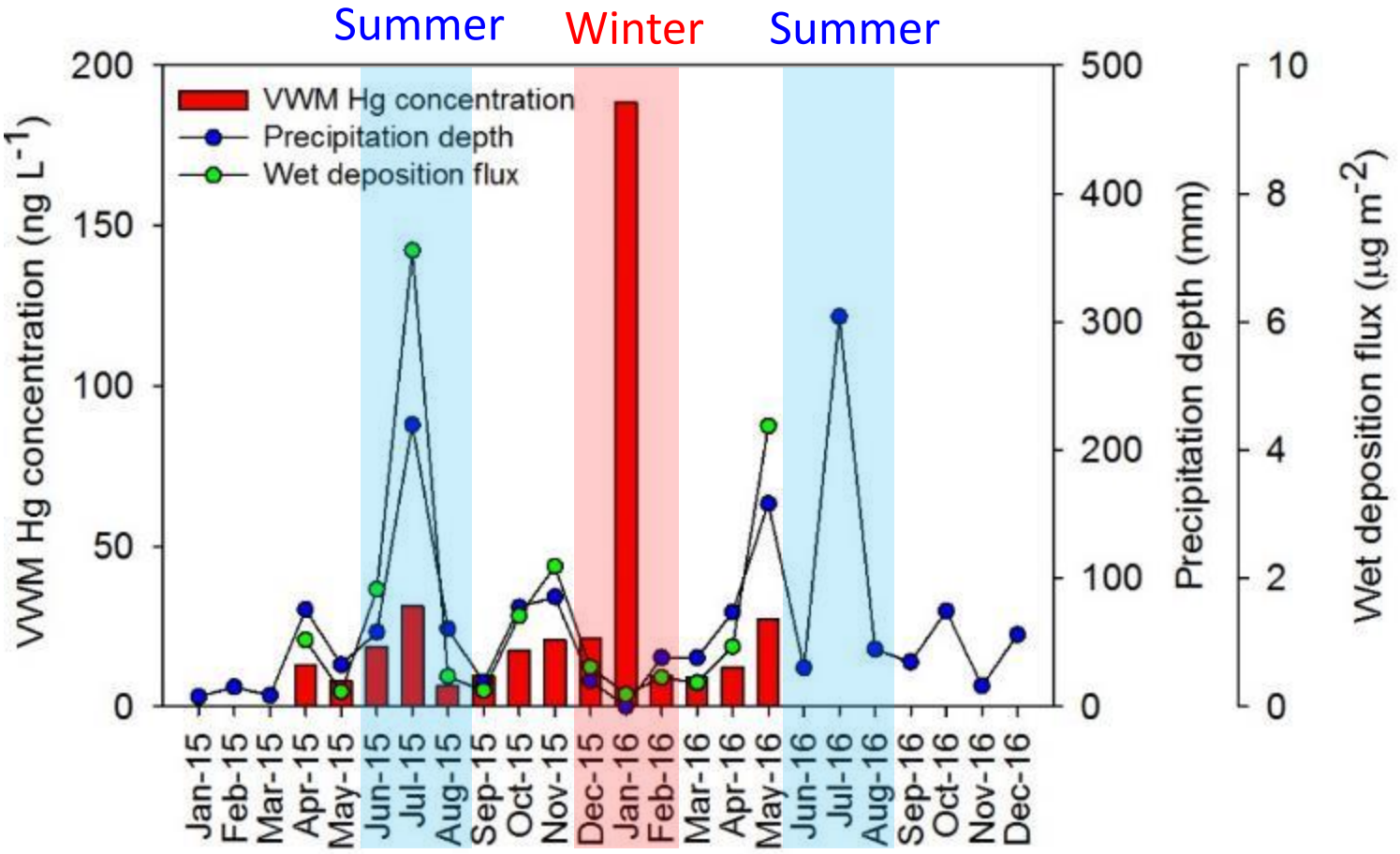
Sea salt (SS) fraction = $\frac{1}{EF} \times 100$

Non-sea salt (NSS) fraction = 100 - $\frac{1}{EF} \times 100$

Source characterization

3. Regional wet deposition

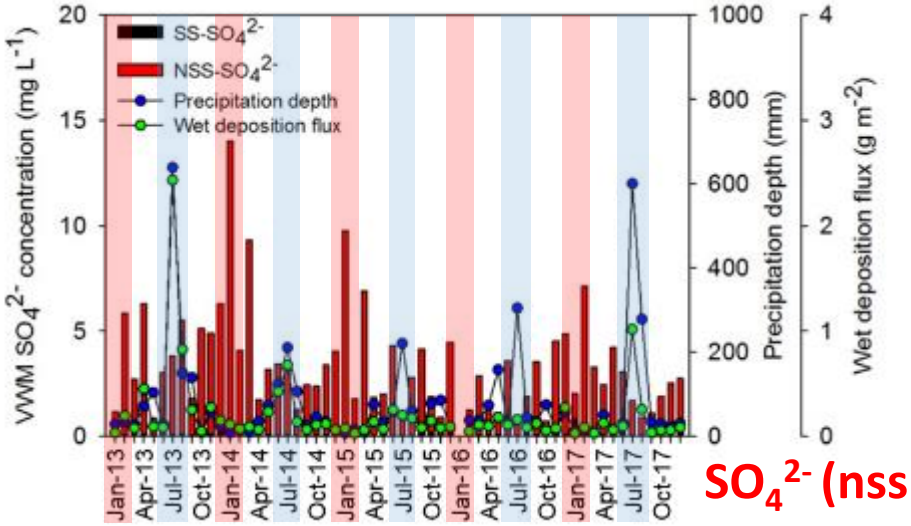
- Seoul (Hg)



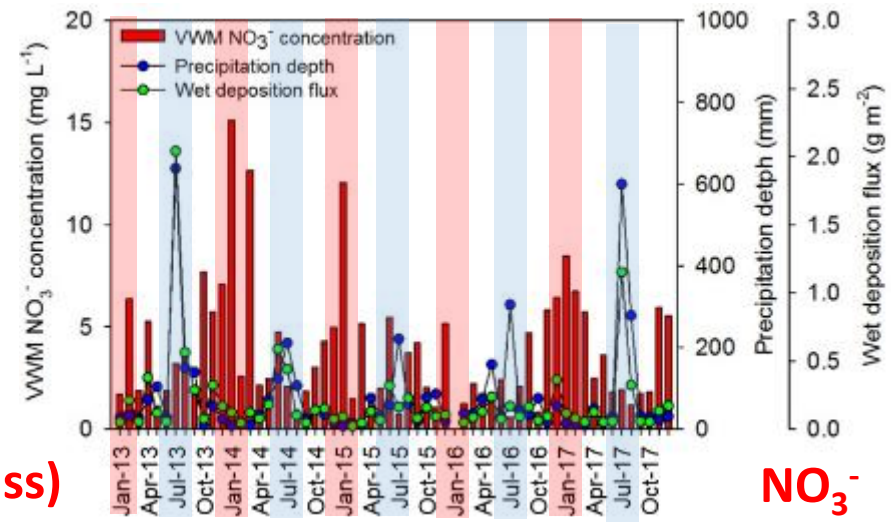
- Seoul: April 2015 – March 2016, THg: 22.6 ng/L, THg flux: 16.1 mg/m^2/yr
- Trend of wet deposition flux follows that of precipitation depth

3. Regional wet deposition

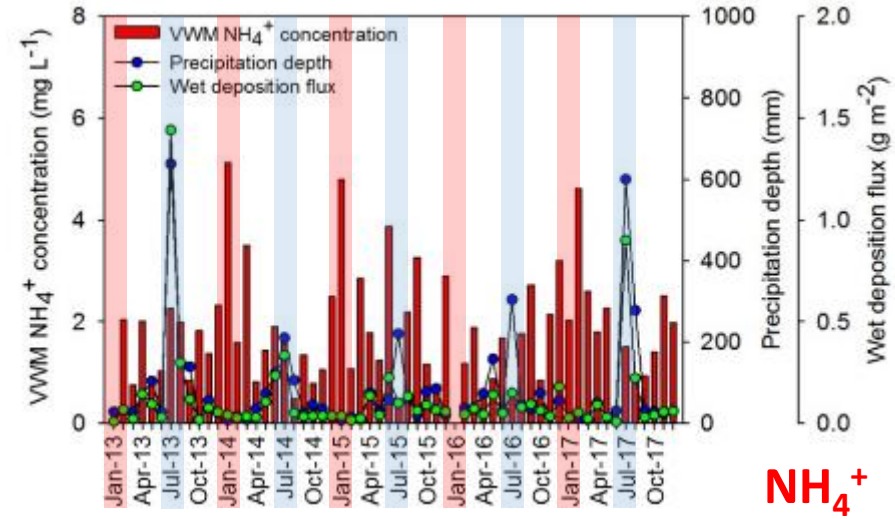
- Seoul (major ions)



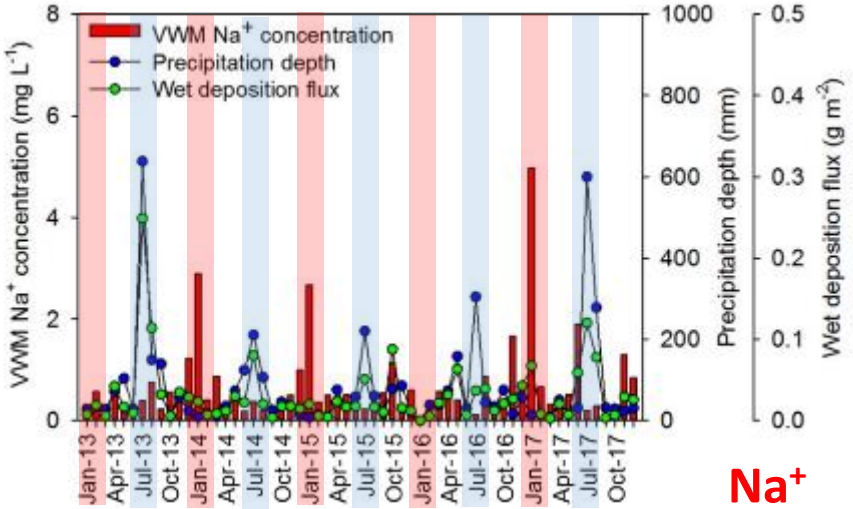
SO_4^{2-} (nss >> ss)



NO_3^-



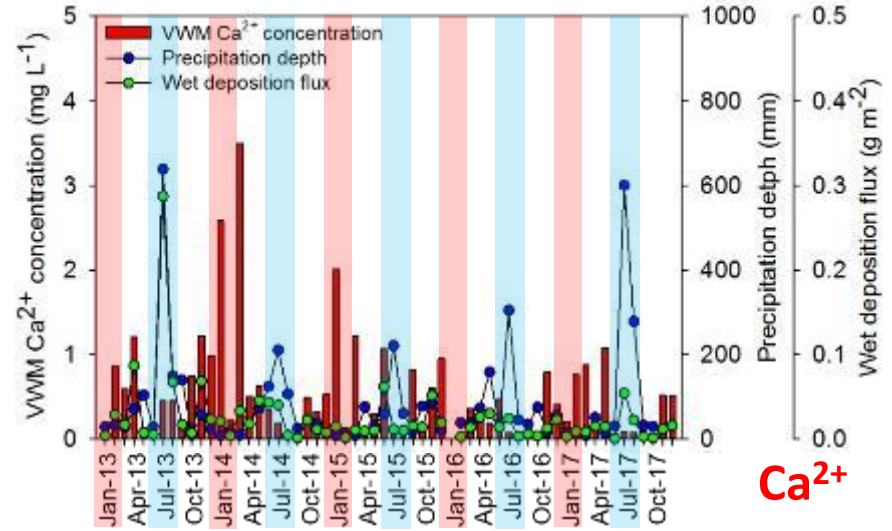
NH_4^+

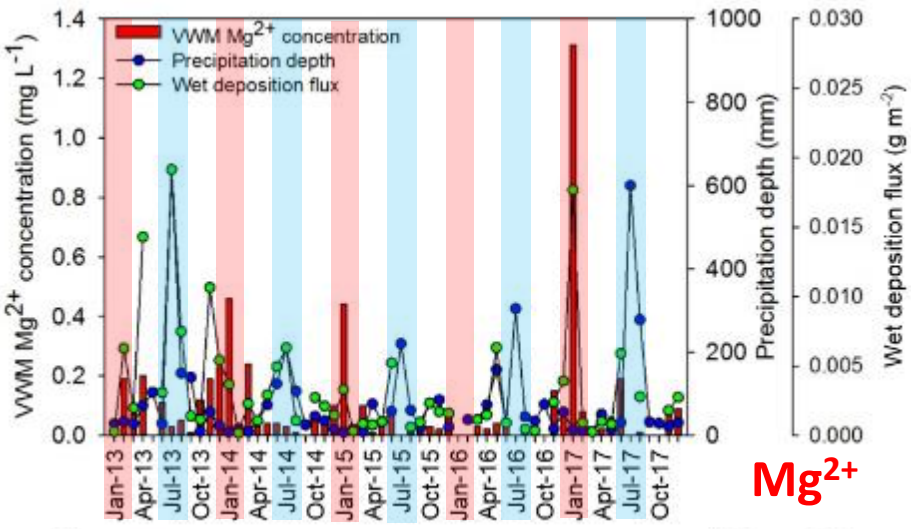


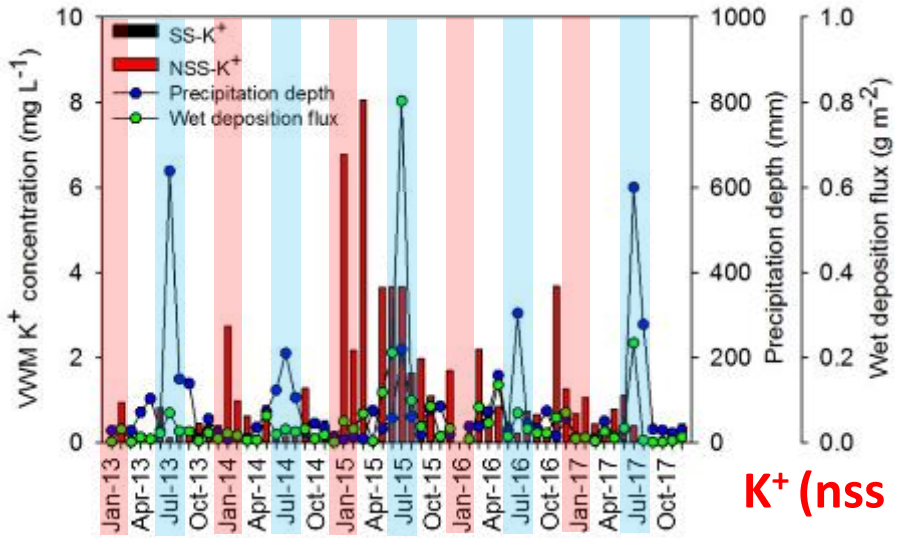
Na^+

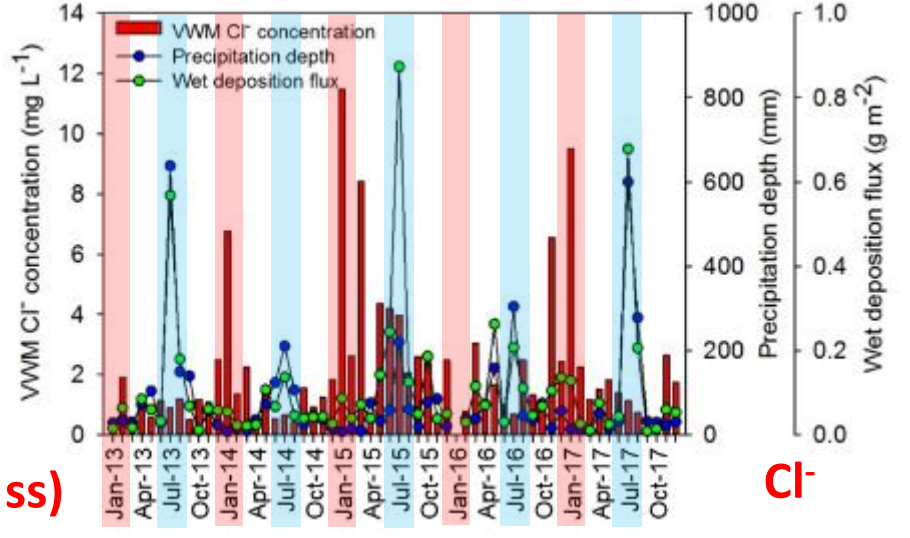
3. Regional wet deposition

- Seoul (major ions)



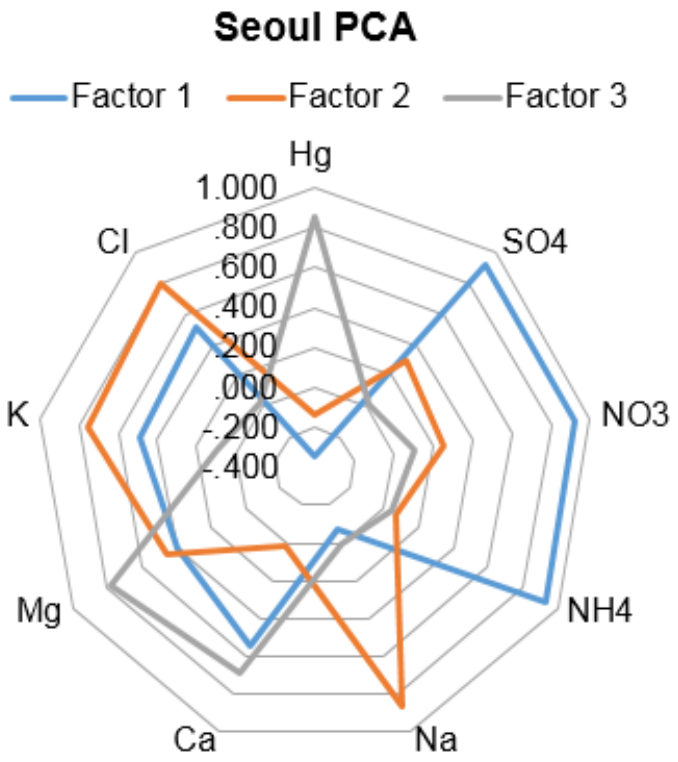






3. Regional wet deposition

- Hg source analysis - Seoul

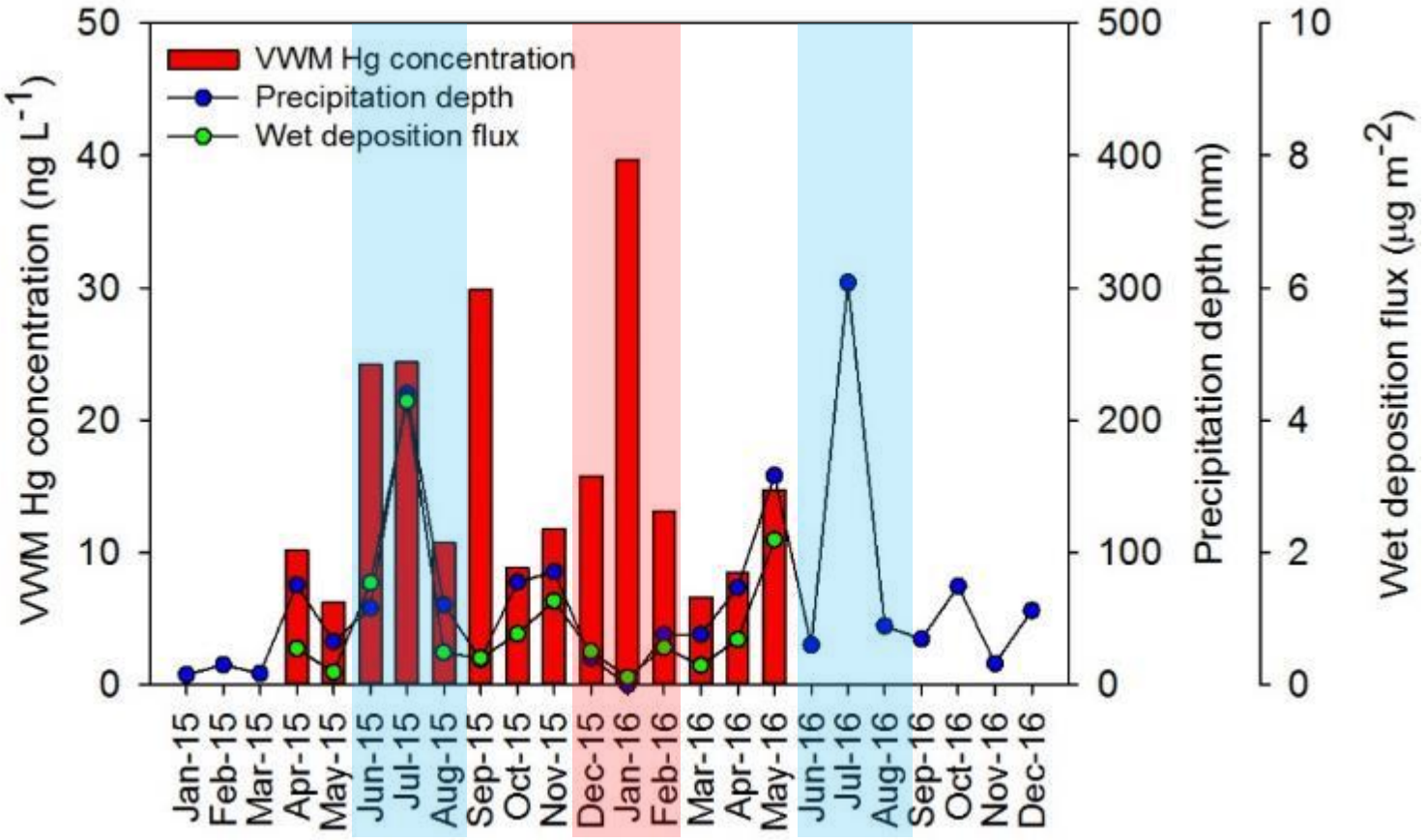


	Factor		
	1	2	3
Hg	-.339	-.136	.852
nss-SO_4^{2-}	.924	.303	.020
NO_3^-	.919	.253	.107
NH_4^+	.938	.070	.038
Na^+	-.074	.867	.000
Ca^{2+}	.552	.014	.696
Mg^{2+}	.400	.459	.784
nss-K^+	.494	.753	.094
Cl^-	.523	.805	.024
Eigen	3.68	2.35	1.84
Var %	40.9	26.2	20.5
Cum %	87.6		

- Hg concentration in Seoul was strongly related to Mg^{2+} and Ca^{2+} (soil dust).

3. Regional wet deposition

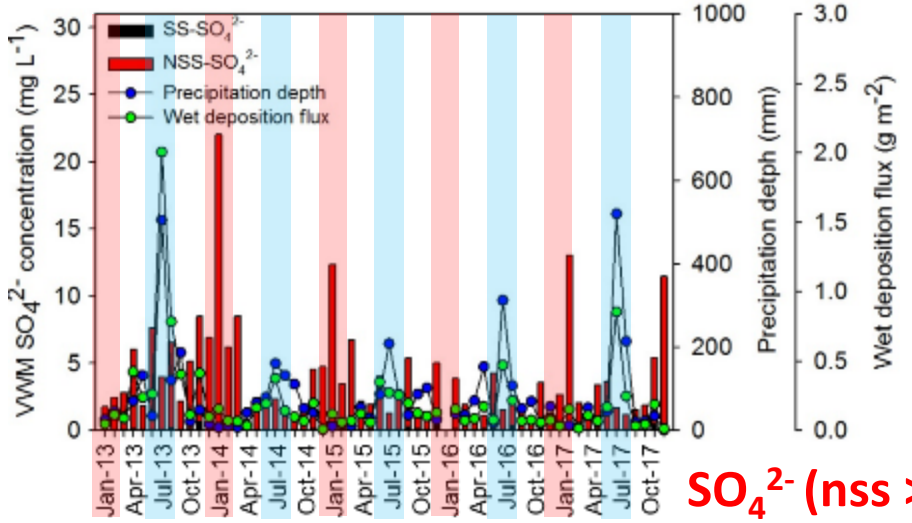
- Incheon (Hg)



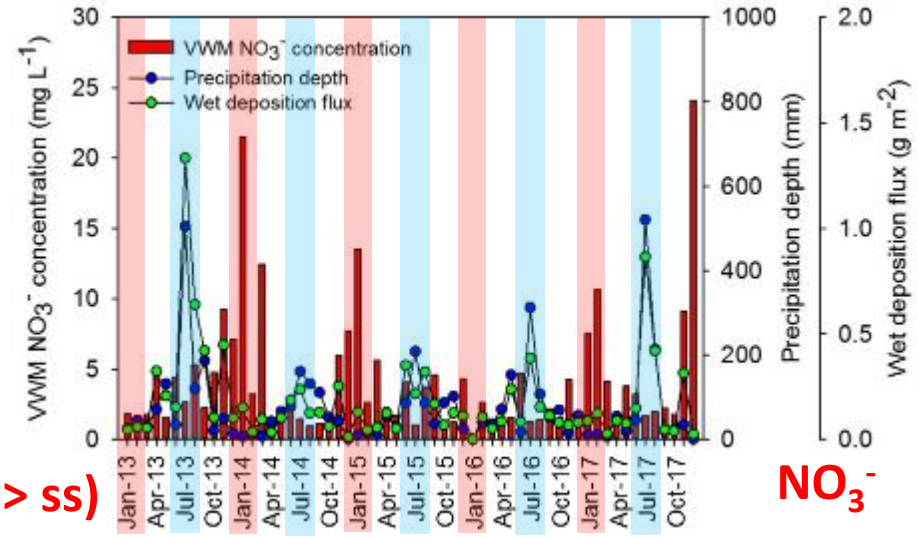
- Incheon: April 2015 – March 2016, THg: 16.8 ng/L, THg flux: 11.0 mg/m^2/yr
- Trend of wet deposition flux follows that of precipitation depth

3. Regional wet deposition

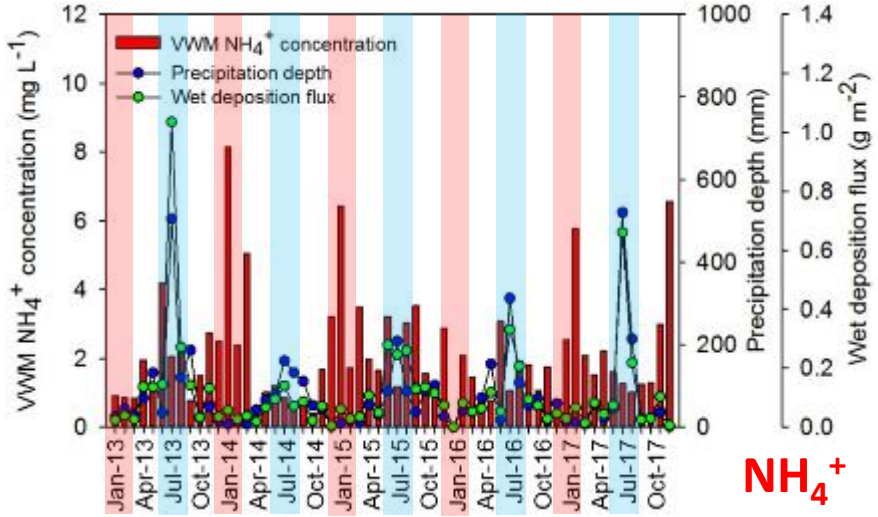
- Incheon (major ions)



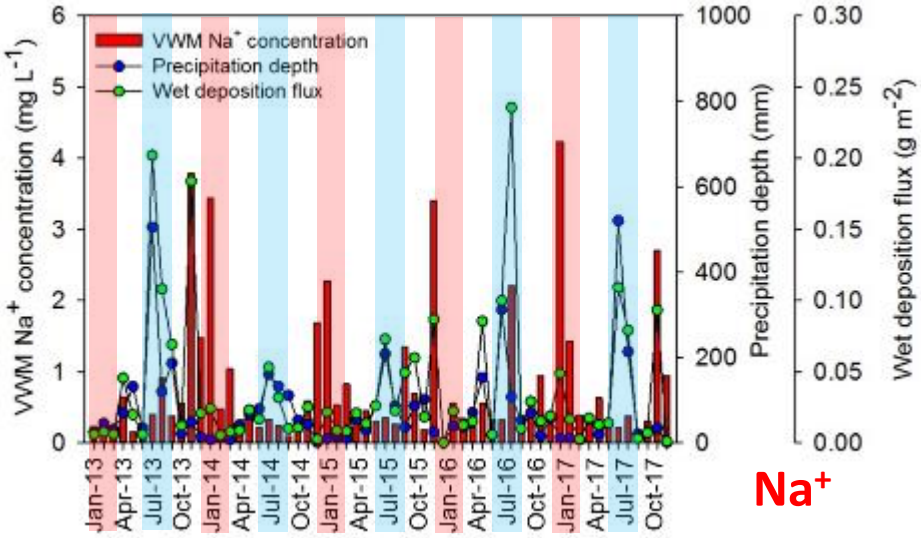
SO_4^{2-} (nss >> ss)



NO_3^-



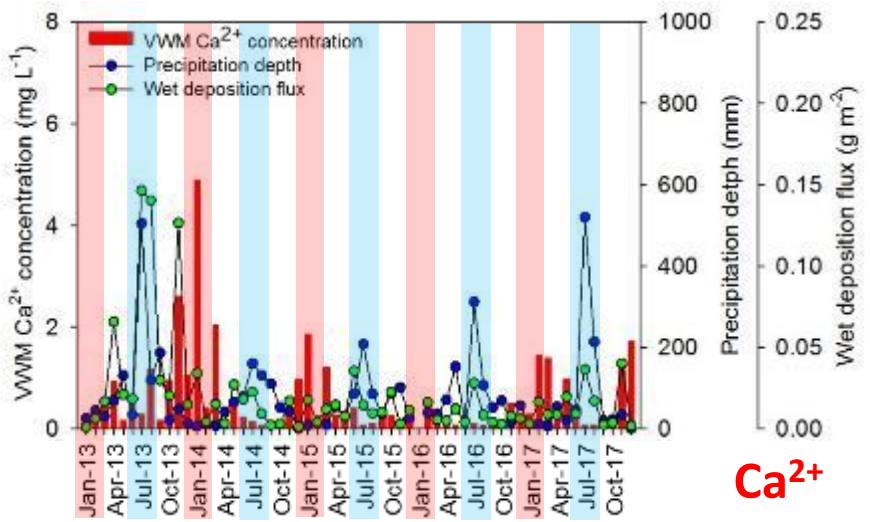
NH_4^+



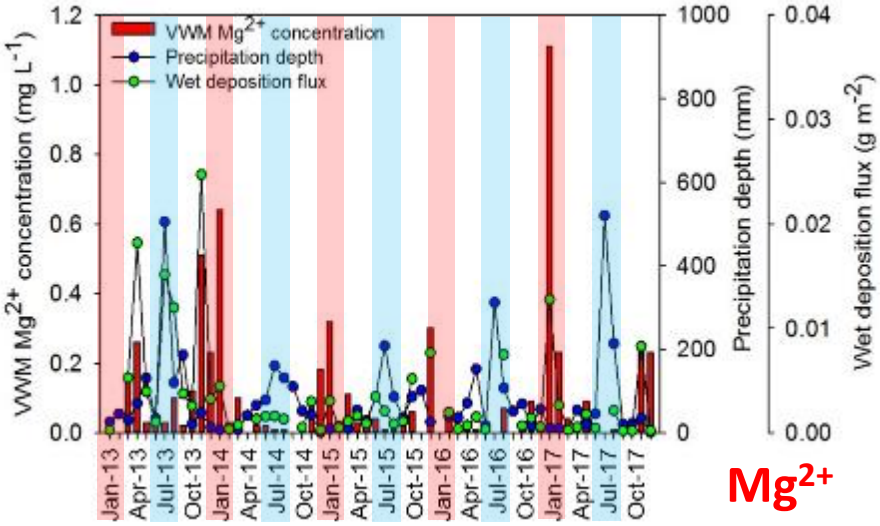
Na^+

3. Regional wet deposition

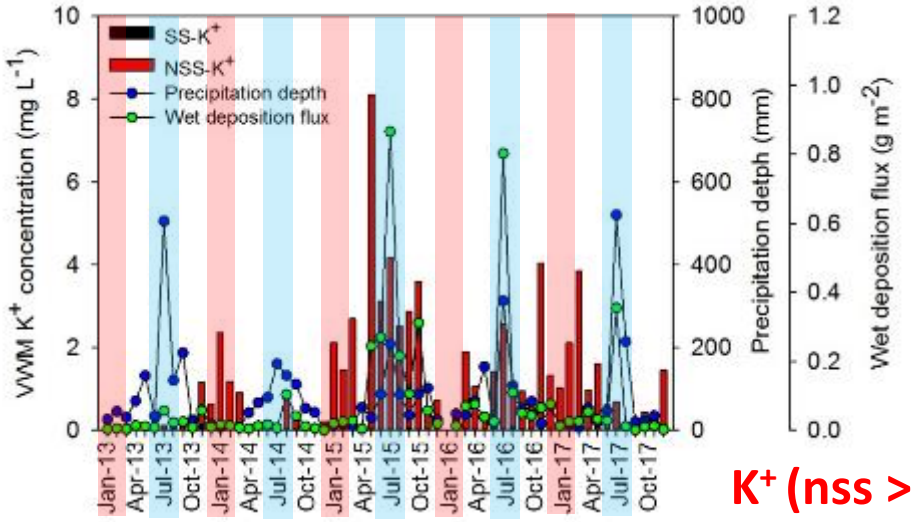
- Incheon (major ions)



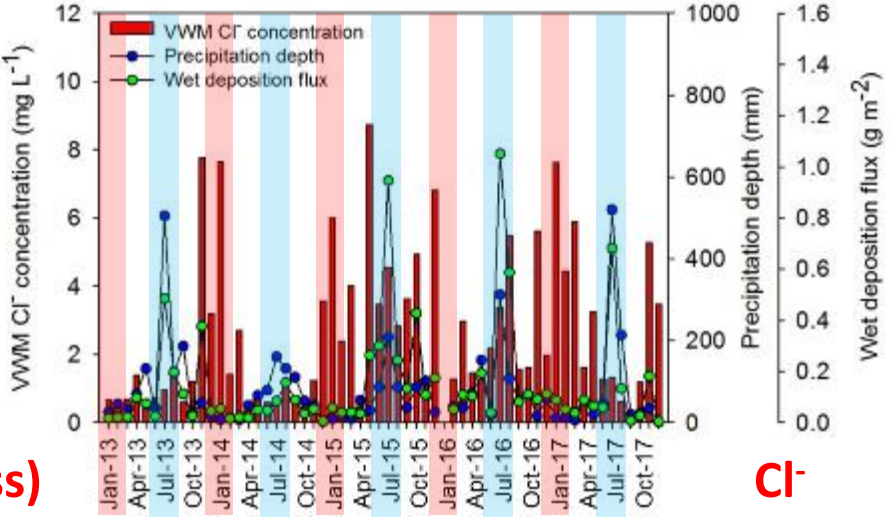
Ca2+



Mg2+



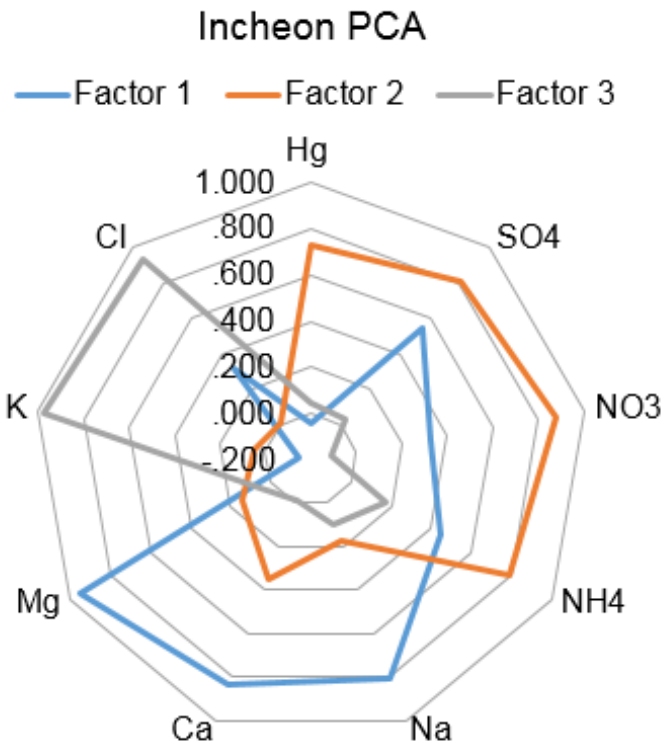
K+ (nss >> ss)



Cl-

3. Regional wet deposition

- Hg source analysis - Incheon

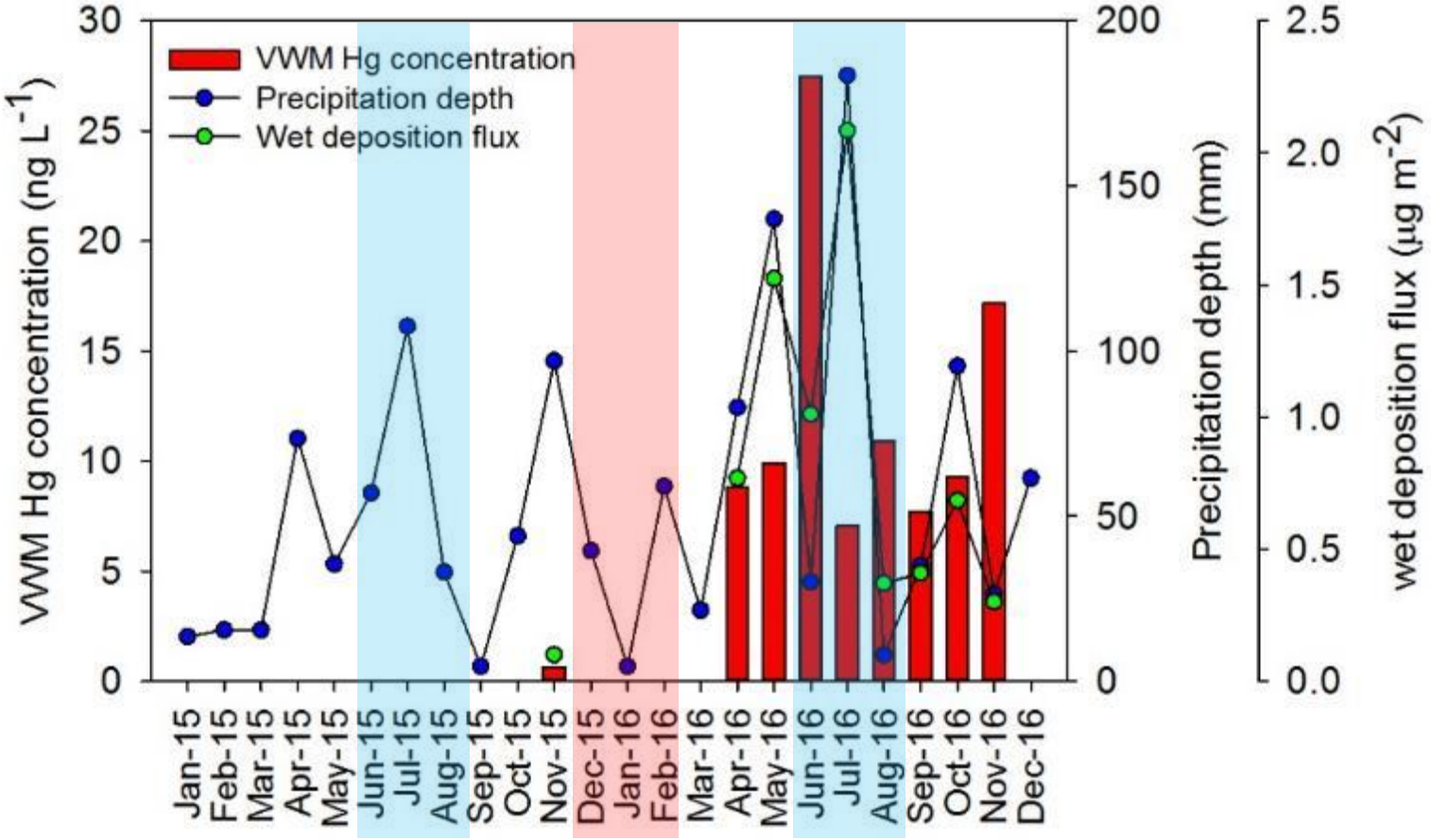


	Factor		
	1	**2**	**3**
Hg	-.044	.727	.047
nss-SO_4^{2-}	.549	.805	.034
NO_3^-	.328	.876	-.115
NH_4^+	.450	.796	.170
Na^+	.804	.174	.094
Ca^{2+}	.839	.347	-.011
Mg^{2+}	.957	.145	.050
nss-K^+	-.151	.051	.974
Cl^-	.311	.010	.936
Eigen	3.00	2.75	1.88
Var %	33.3	30.6	20.9
Cum %	84.9		

- Hg concentration in Incheon was highly related to SO_4^{2-}, NO_3^-, NH_4^+ (power plants and vehicles), attributable to vicinity of coal power plants.

3. Regional wet deposition

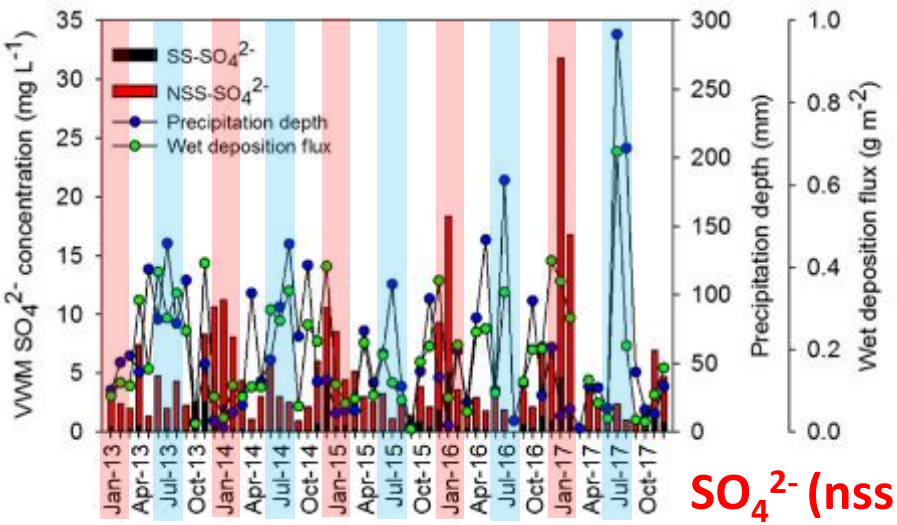
- Taean (Hg)



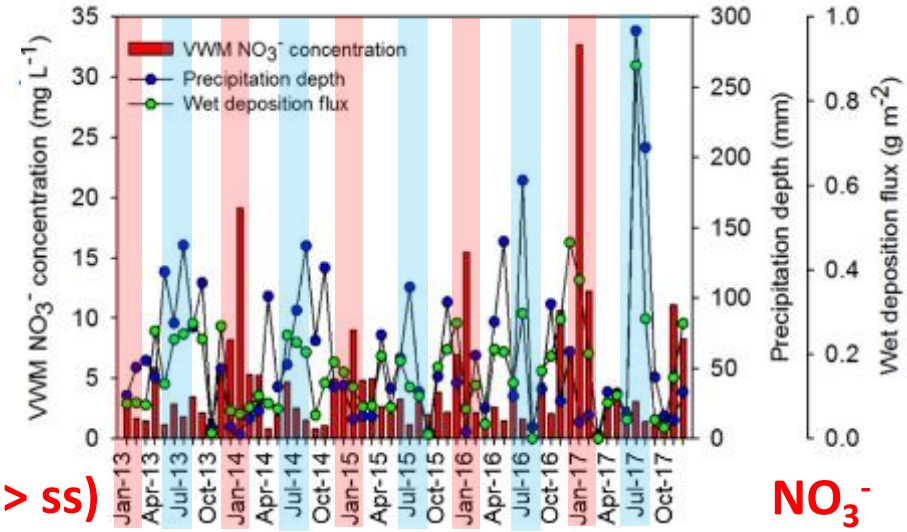
- Taean: November 2015, March 2016 – December 2016
- Trend of wet deposition flux follows that of precipitation depth

3. Regional wet deposition

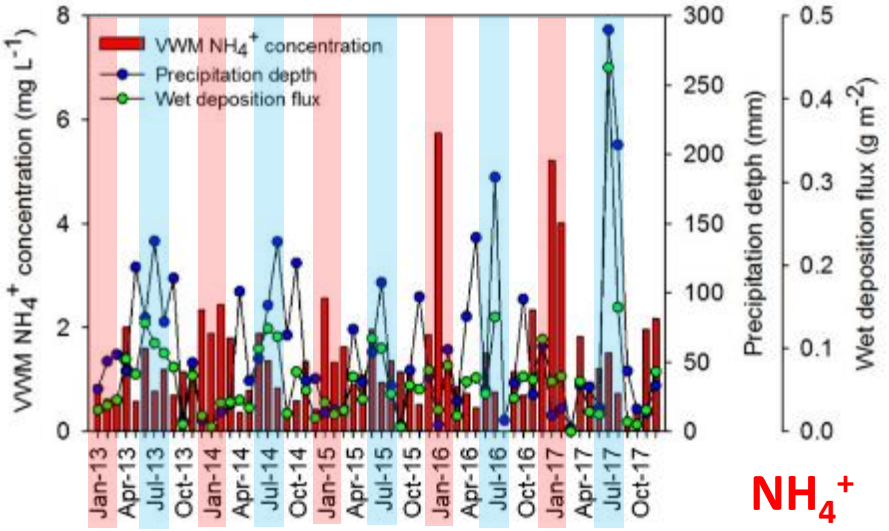
- Taean (major ions)



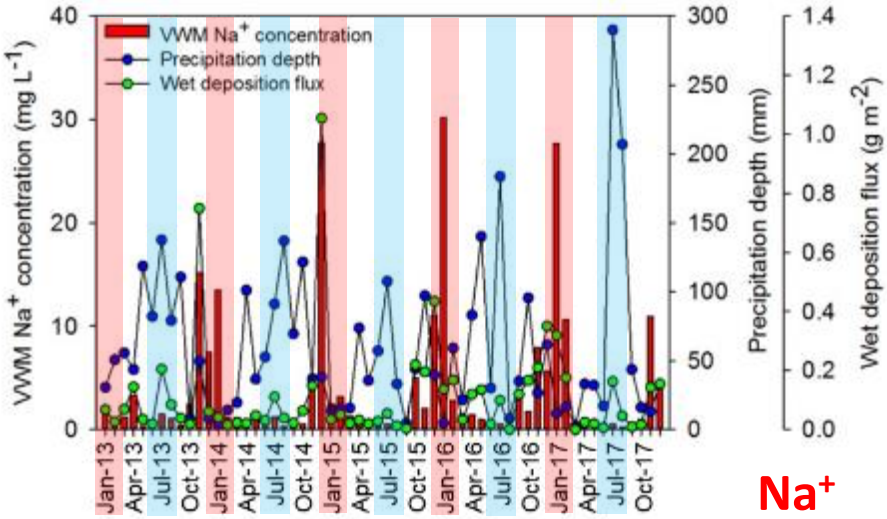
SO_4^{2-} (nss >> ss)



NO_3^-



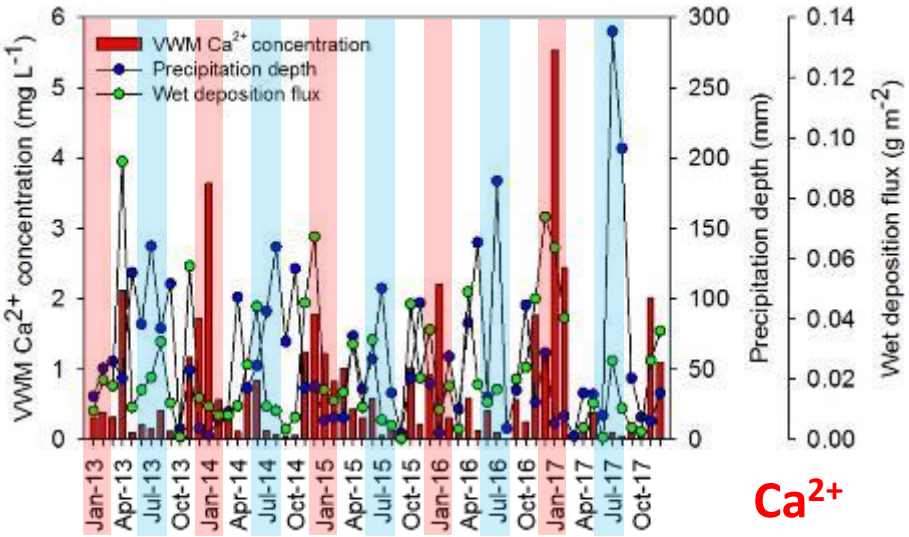
NH_4^+

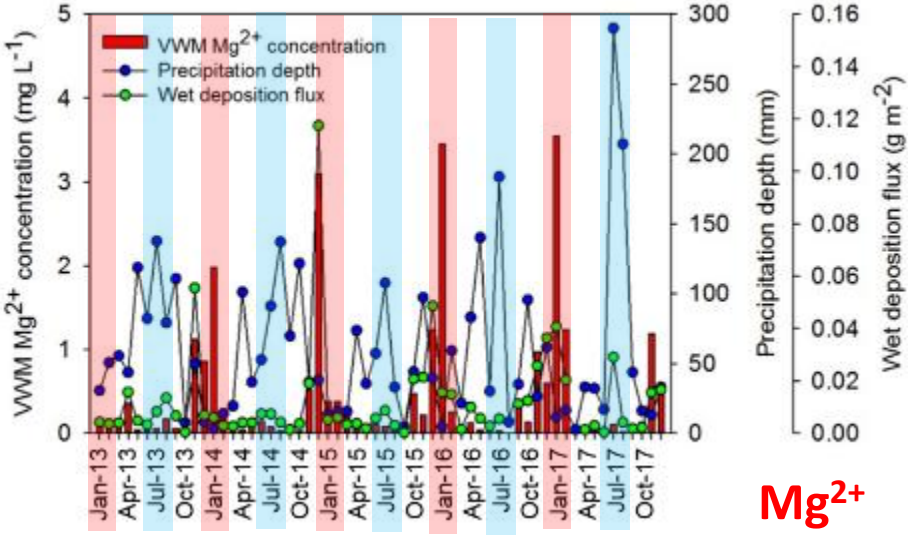


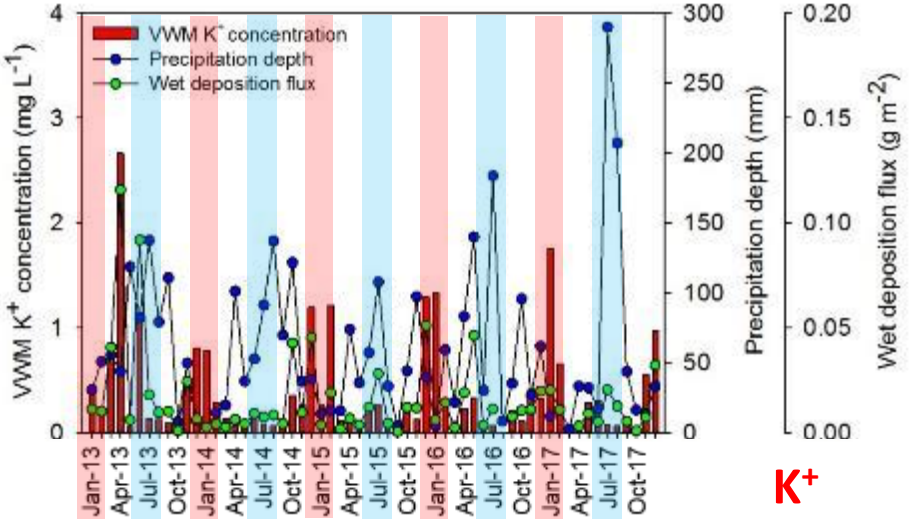
Na^+

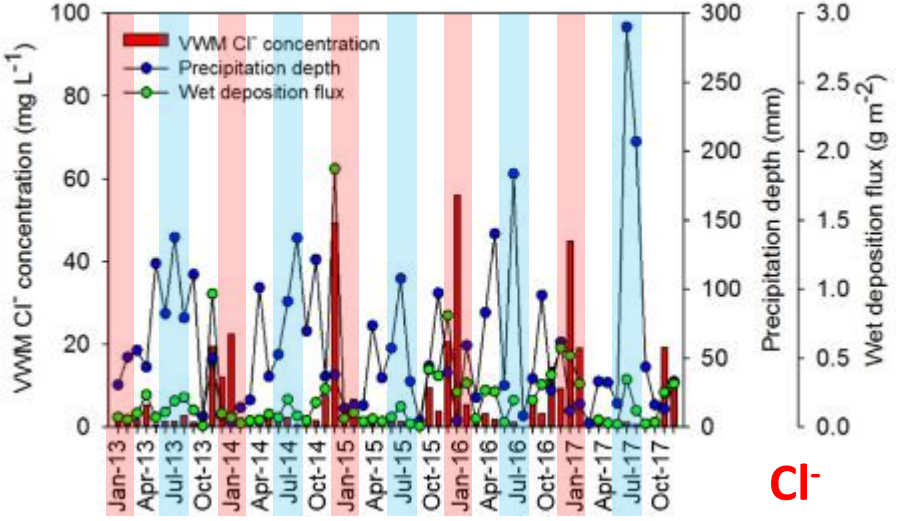
3. Regional wet deposition

- Taean (major ions)



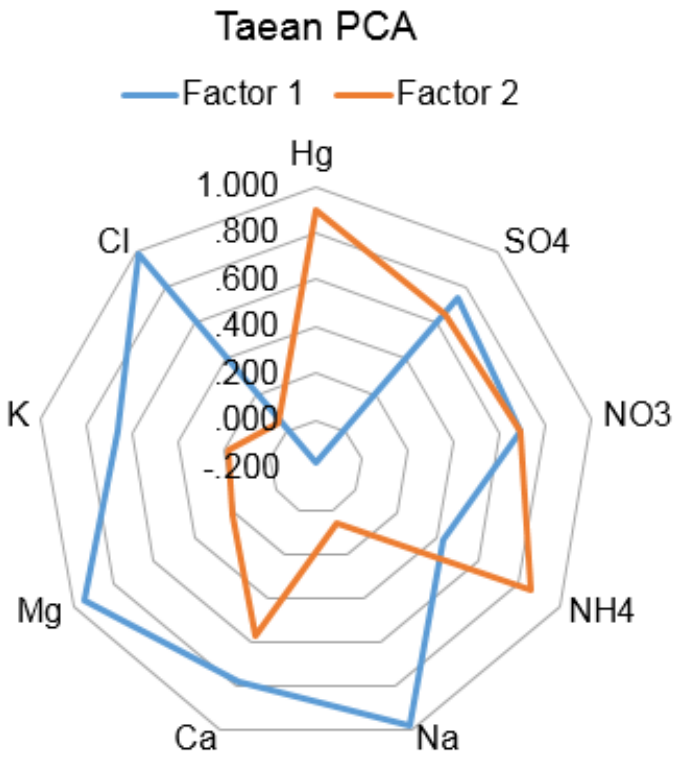






3. Regional wet deposition

- Hg source analysis - Taean

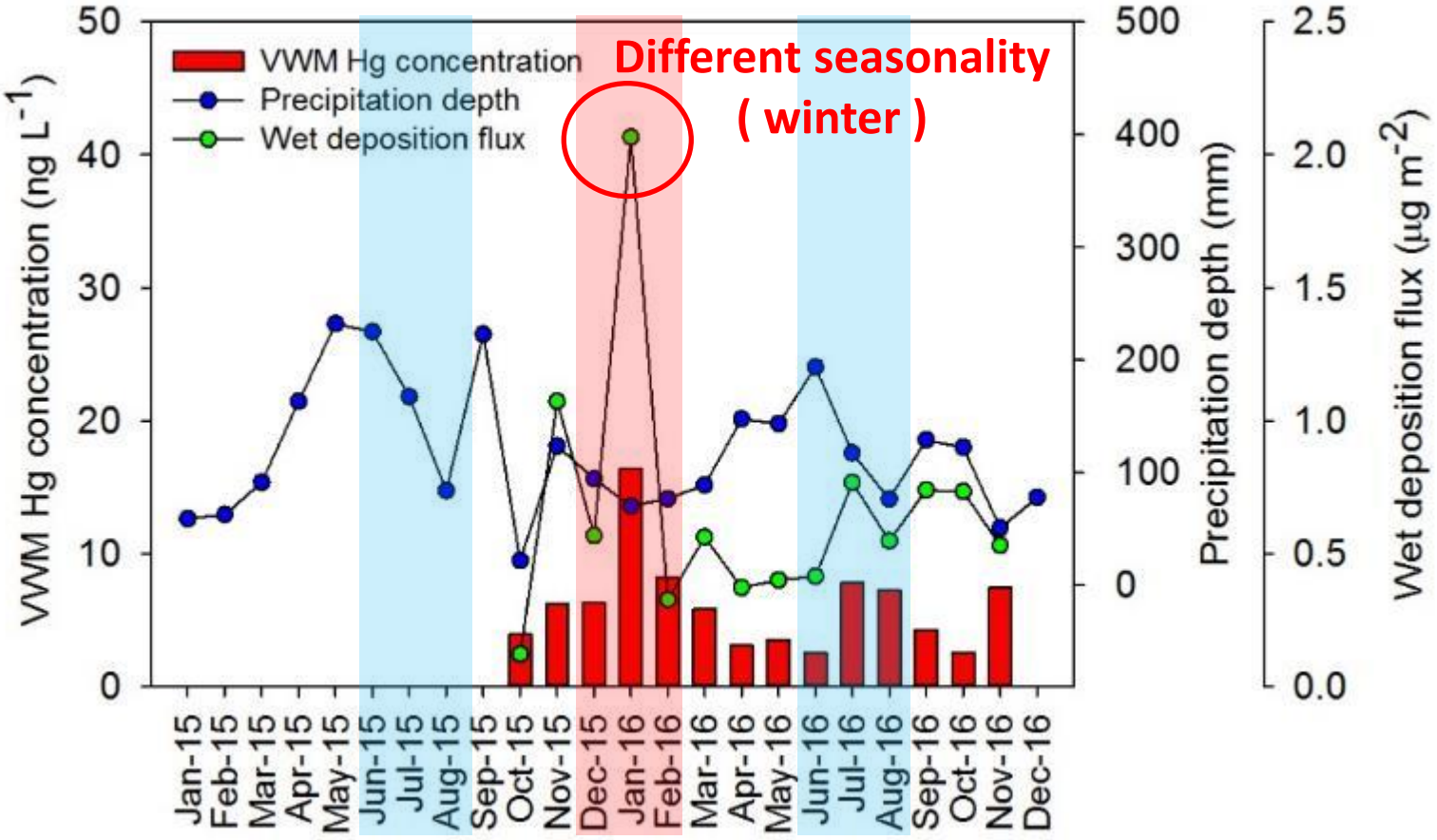


Factor		
	1	2
Hg	-.183	.897
nss-SO_4^{2-}	.740	.654
NO_3^-	.690	.686
NH_4^+	.423	.859
Na^+	.979	.052
Ca^{2+}	.780	.568
Mg^{2+}	.949	.216
K^+	.663	.183
Cl^-	.984	.045
Eigen	5.11	2.85
Var %	56.8	31.6
Cum %	88.4	

- Hg concentration in Taean was strongly related to NH_4^+ (power plants, vehicles), attributable to locality of coal power plants.

3. Regional wet deposition

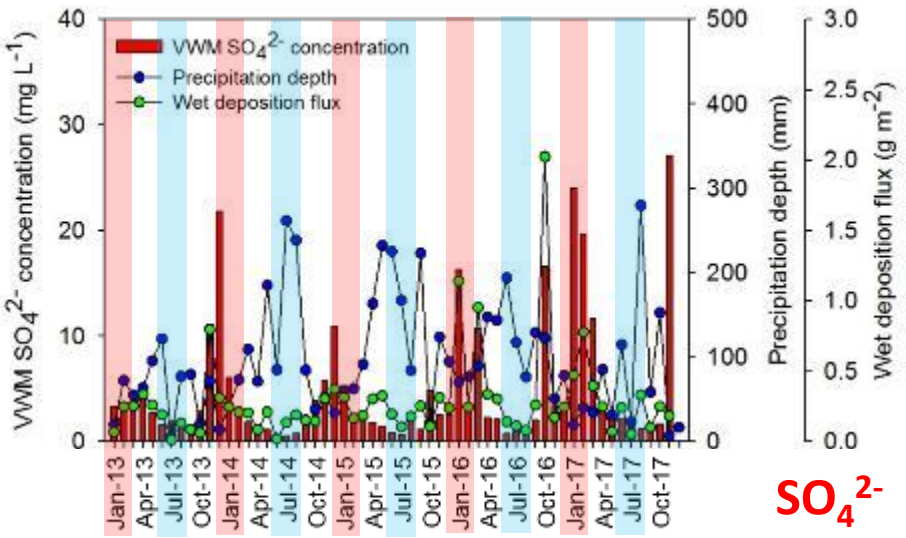
- Jeju (Hg)



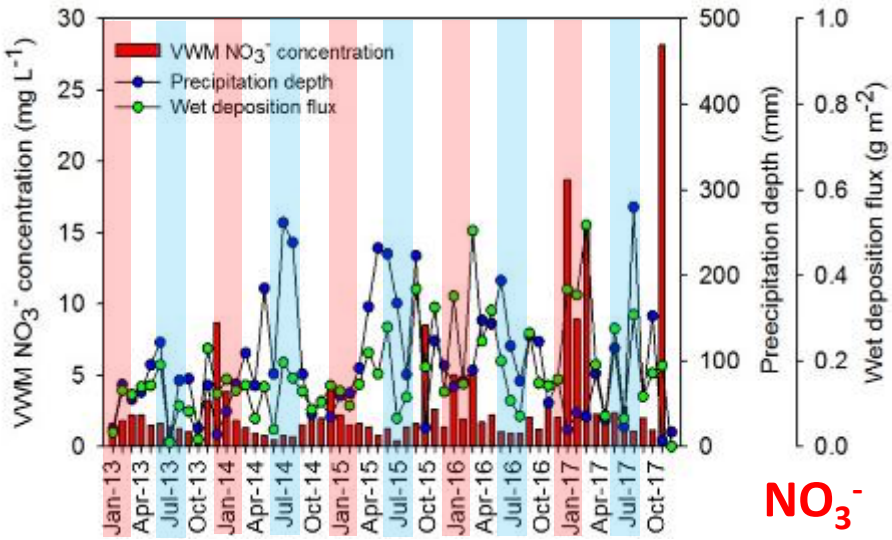
- Jeju: Oct 2015 – Sep 2016, THg: 4.5 ng/L, THg flux: 8.0 mg/m^2/yr
- Different seasonality of wet deposition flux from the other sites

3. Regional wet deposition

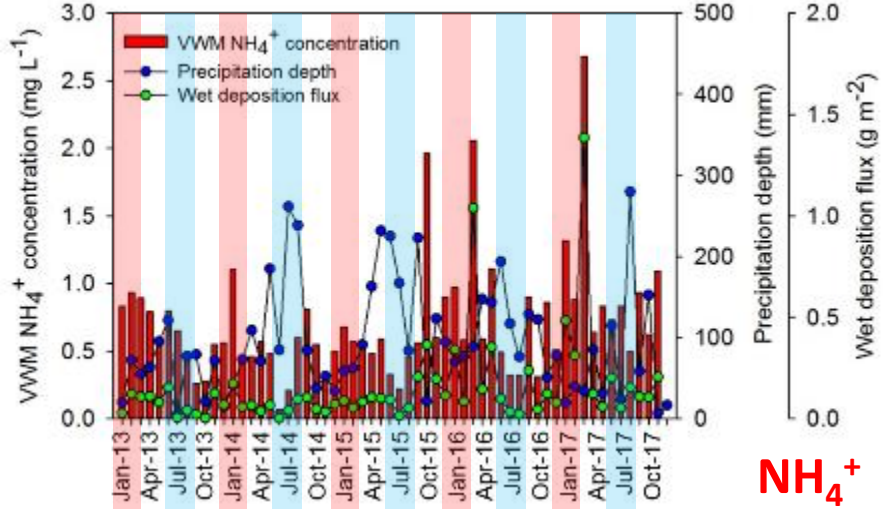
- Jeju (major ions)



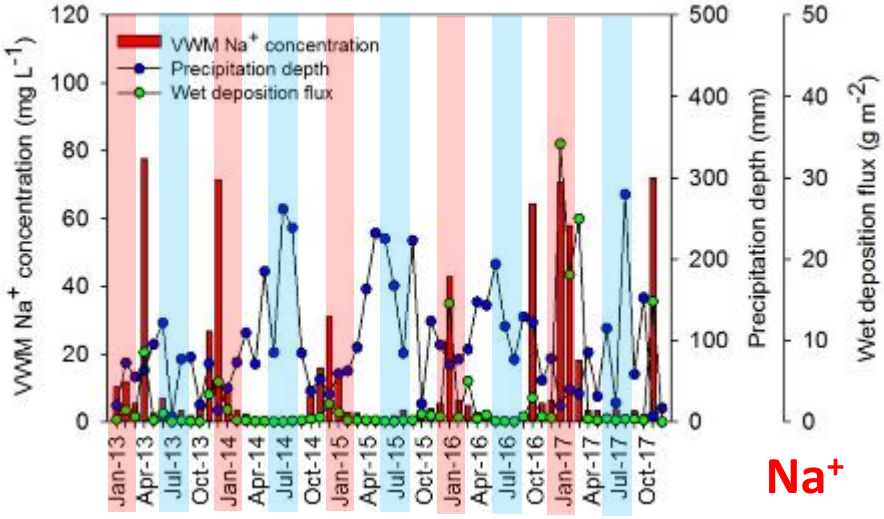
SO_4^{2-}



NO_3^-



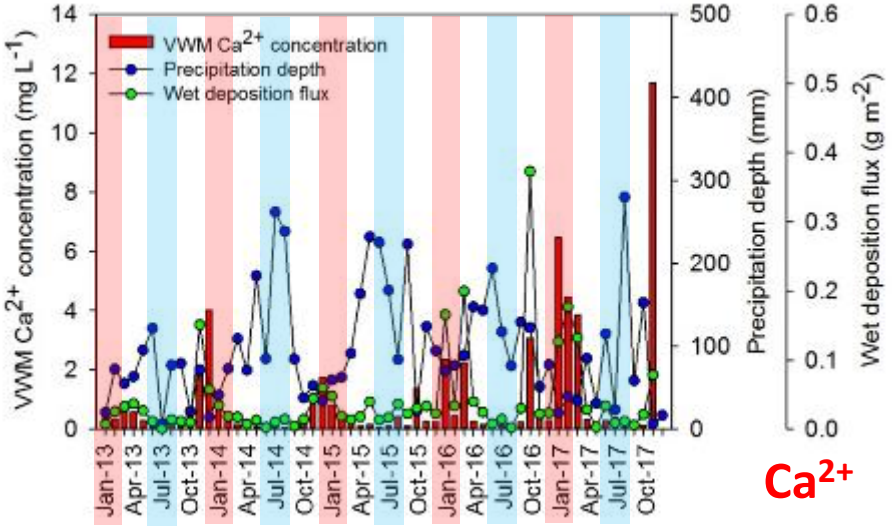
NH_4^+

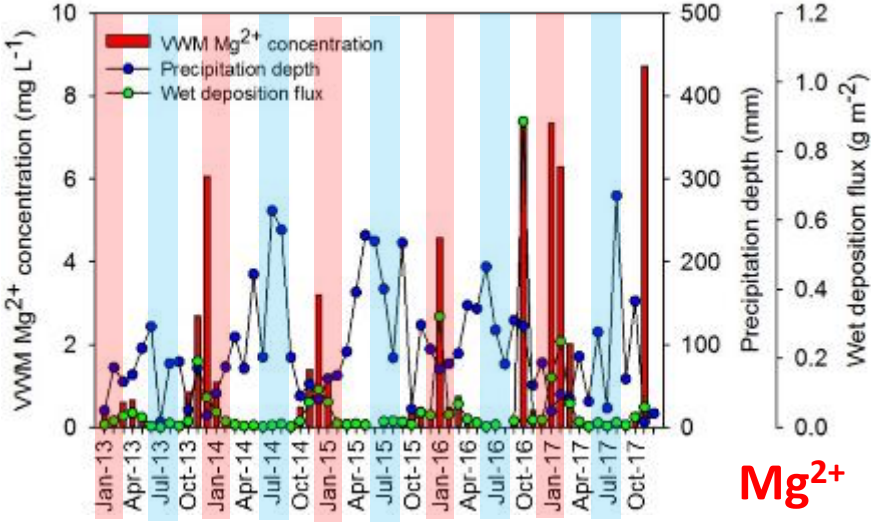


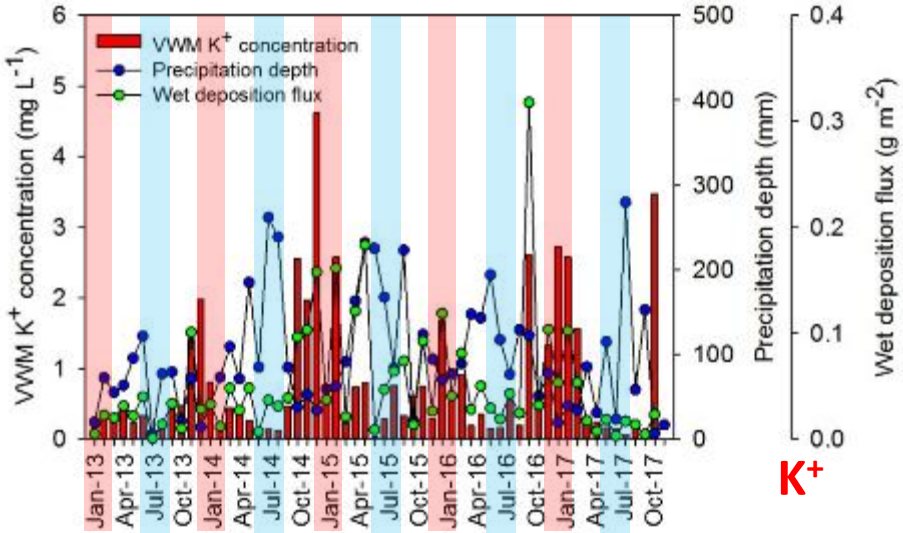
Na^+

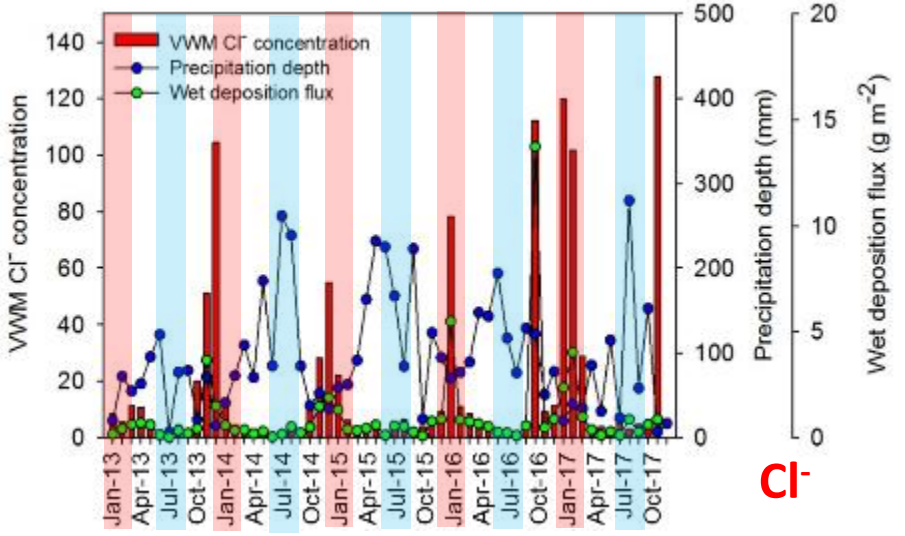
3. Regional wet deposition

- Jeju (major ions)



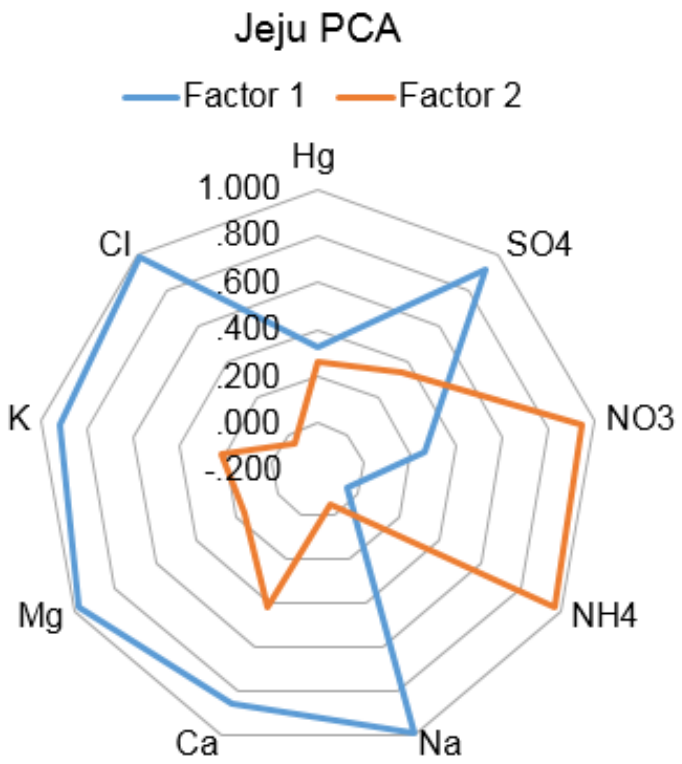






3. Regional wet deposition

- Hg source analysis - Jeju

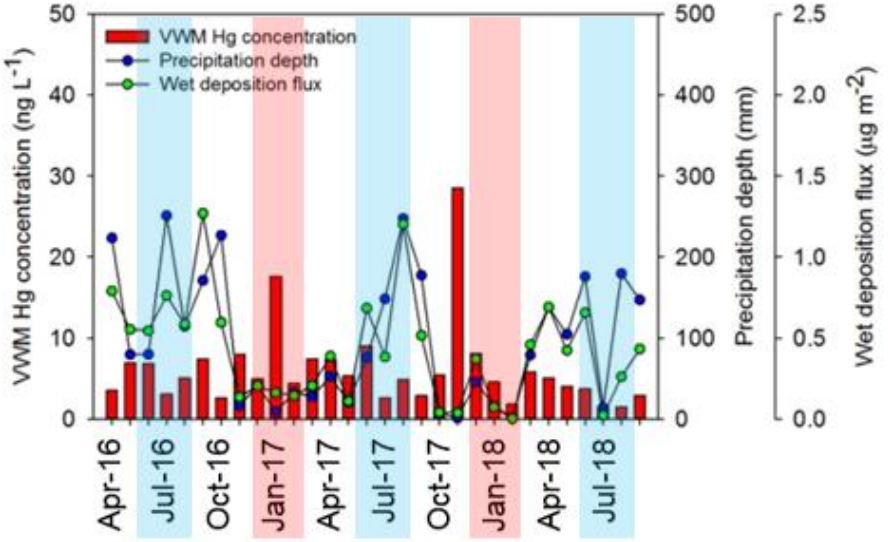


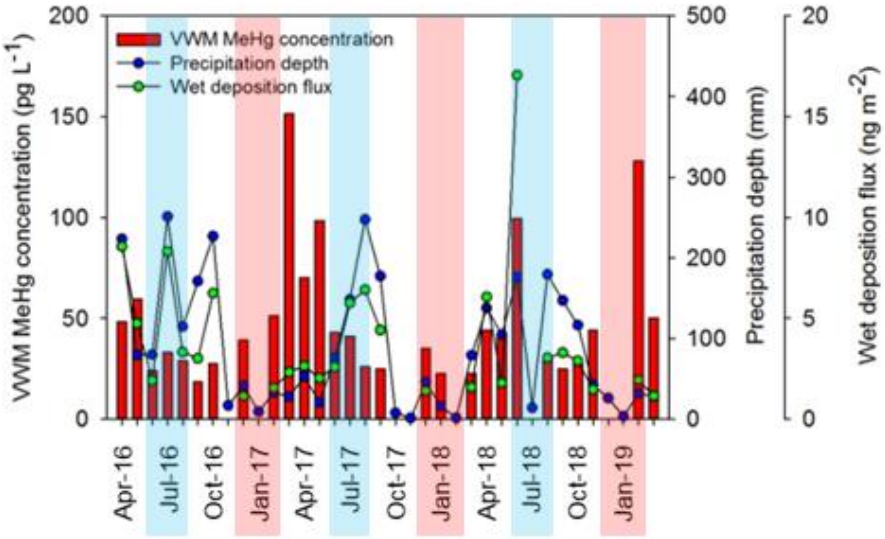
	Factor	
	1	**2**
Hg	.326	.265
SO_4^{2-}	.918	.350
NO_3^-	.266	.941
NH_4^+	-.052	.964
Na^+	.989	-.049
Ca^{2+}	.863	.425
Mg^{2+}	.975	.163
K^+	.920	.217
Cl^-	.985	-.049
Eigen	5.51	2.23
Var %	61.2	25.2
Cum %	86.4	

- Hg concentration in Jeju was weakly related to Na^+ and Cl^- ions (marine and dust sources)

3. Regional wet deposition

- Gwangju (Hg, MeHg)

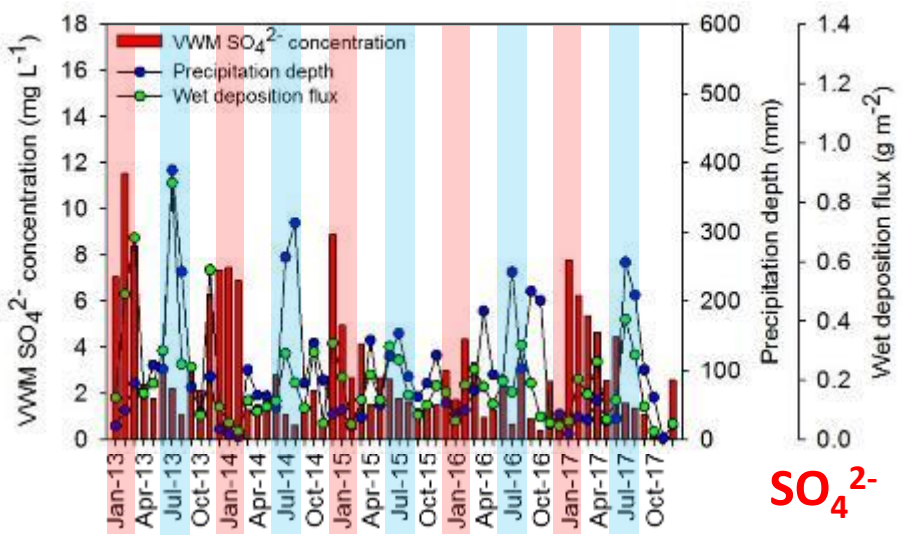




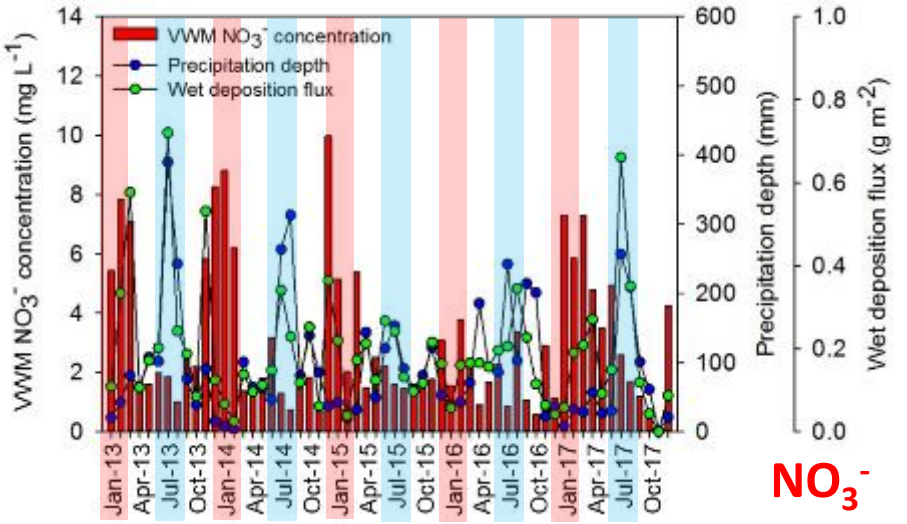
- April 2016-March 2017
  THg: 4.7 ng/L, THg flux: 6.0 mg/m^2
- April 2017-March 2018
  THg: 4.9 ng/L, THg flux: 4.3 mg/m^2
- April 2016-March 2017
  MeHg: 35.2pg/L, MeHg flux: 44.1ng/m^2
- April 2017-March 2018
  MeHg: 33.8pg/L, MeHg flux: 30.3ng/m^2
- April 2018-March 2019
  MeHg: 50.7pg/L, MeHg flux: 65.5ng/m^2

3. Regional wet deposition

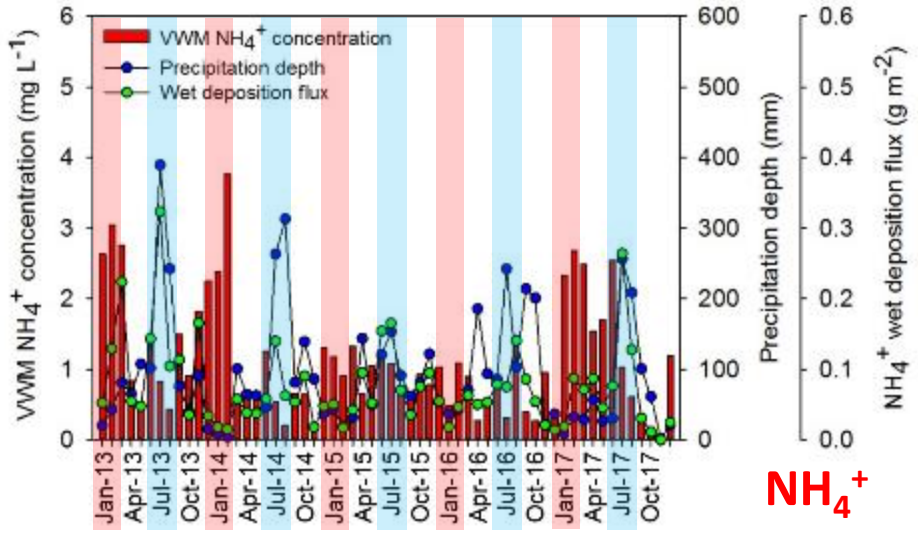
- Gwangju (major ions)



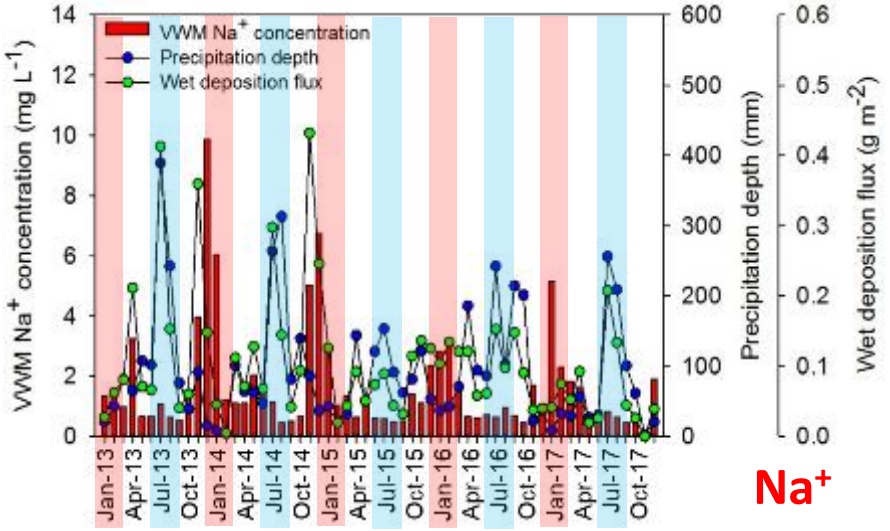
SO_4^{2-}



NO_3^-



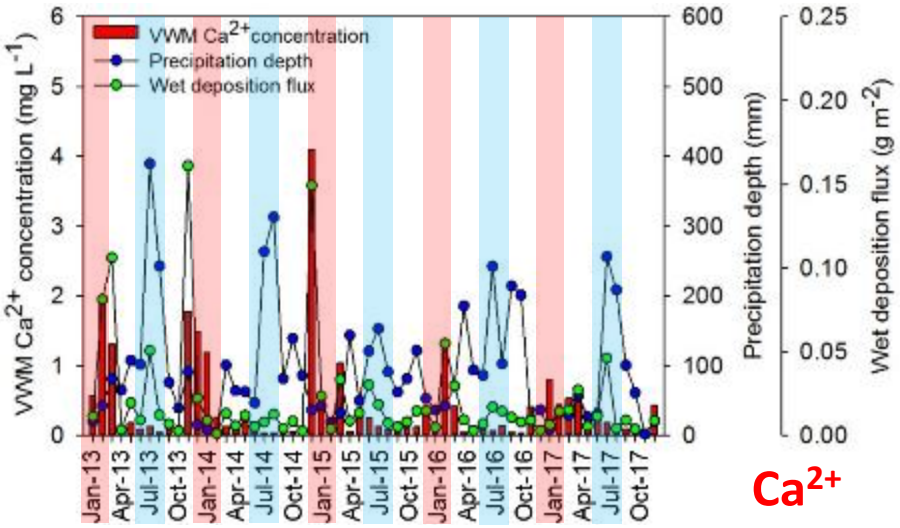
NH_4^+



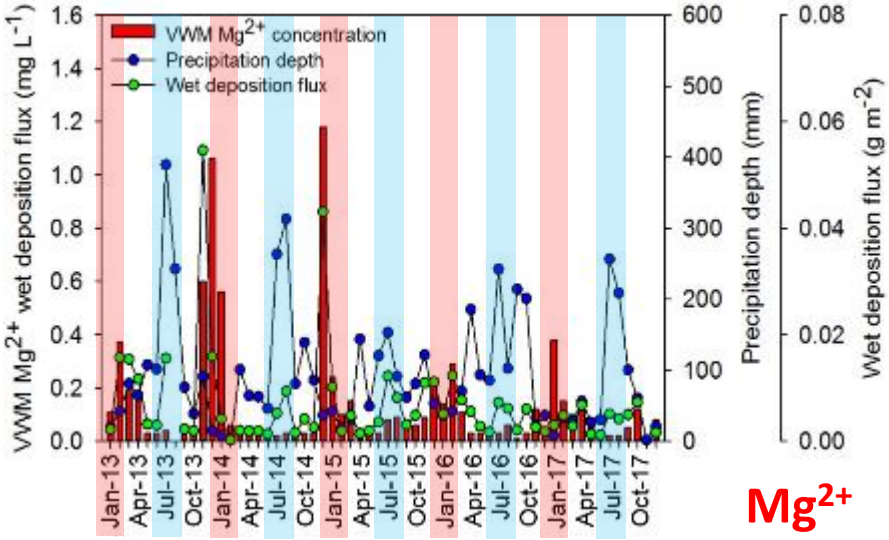
Na^+

3. Regional wet deposition

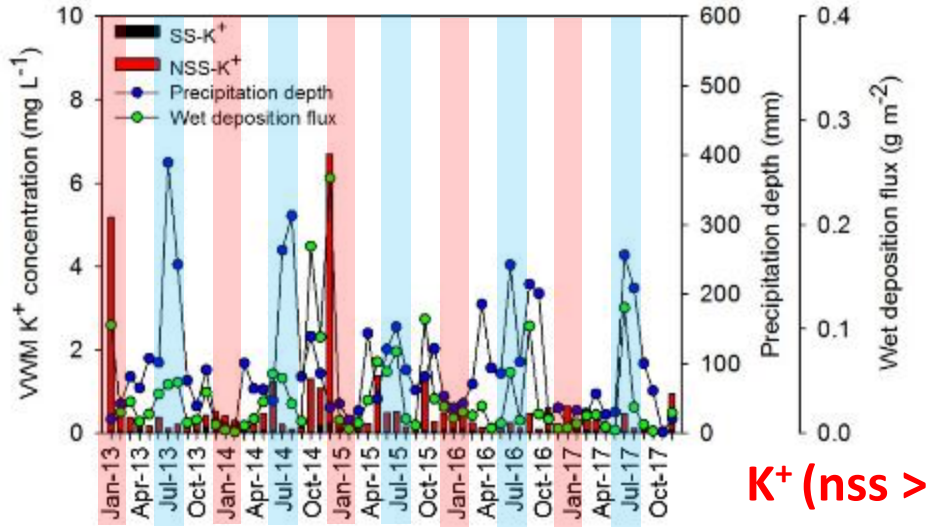
- Gwangju (major ions)



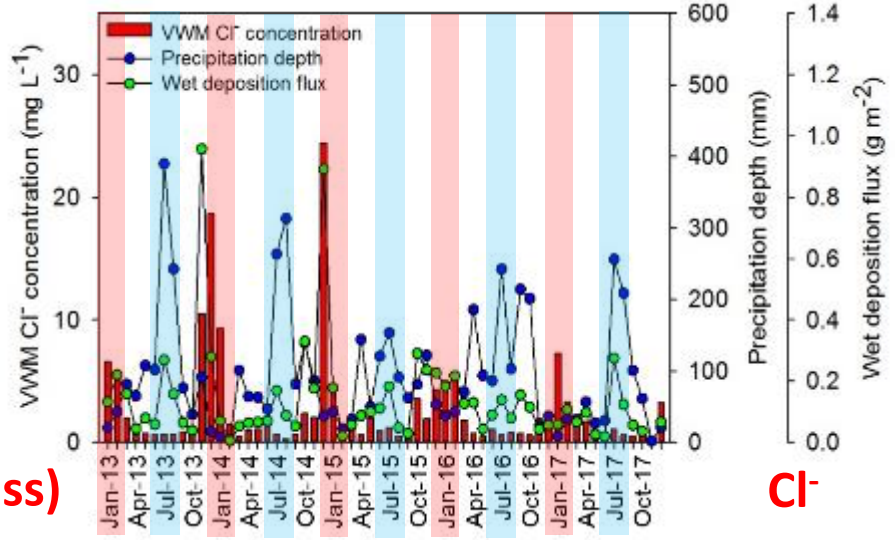
Ca2+



Mg2+



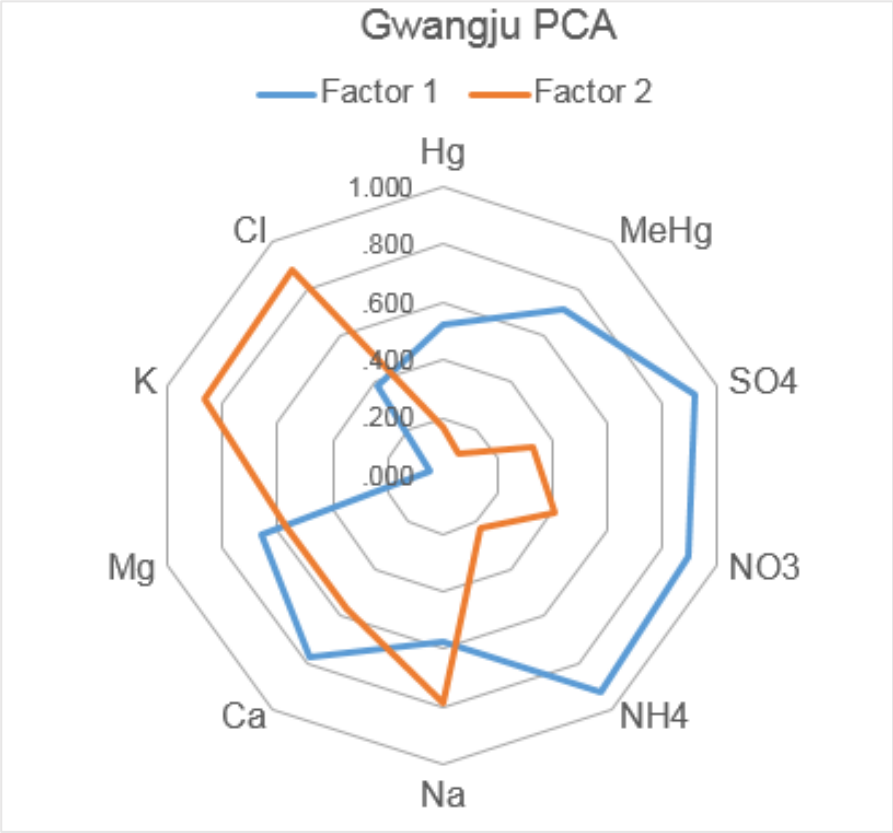
K+ (nss >> ss)



Cl-

3. Regional wet deposition

- Hg, MeHg source analysis - Gwangju

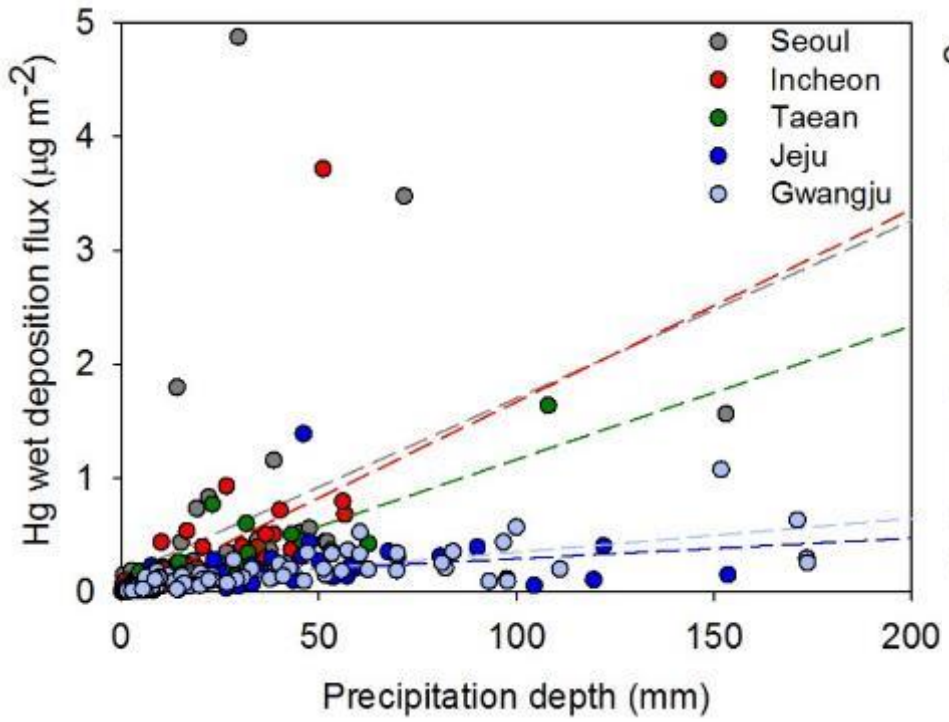


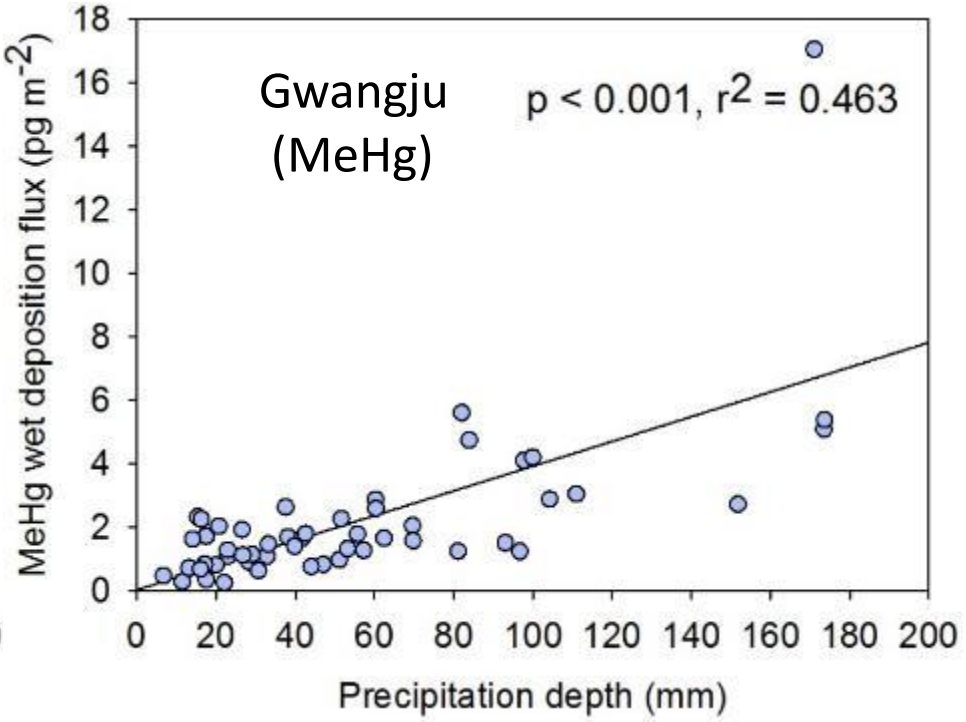
	Factor	
	1	**2**
Hg	.522	.164
MeHg	.711	.092
SO_4^{2-}	.914	.328
NO_3^-	.897	.408
NH_4^+	.925	.227
Na^+	.573	.784
Ca^{2+}	.779	.569
Mg^{2+}	.657	.568
K^+	.045	.862
Cl^-	.387	.883
Eigen	4.79	3.15
Var %	47.9	31.5
Cum %	79.4	

- Hg and MeHg concentration in Gwangju was related to SO_4^{2-}, NO_3^-, NH_4^+ ions (power plants and vehicles).

3. Regional wet deposition

- In-cloud vs below-cloud scavenging





Site	Seoul	Incheon	Taean	Jeju	Gwangju
p value	< 0.001	< 0.001	< 0.001	0.03	< 0.001
r square	0.216	0.298	0.723	0.0921	0.539

Site	Gwangju
p value	< 0.001
r square	0.463

- Significant correlation between precipitation and Hg wet deposition flux indicates dominance of the in-cloud scavenging process.

4. Summary

Site	Annual concentration (ng L^{-1})	Annual Wet deposition flux ($\mu g\ m^{-2}$)	Factors controlling total ions distribution (Factor 1)	Factors controlling Hg distribution	In-cloud vs Below-cloud
Seoul	23	16	Anthropogenic	Soil dust	In-cloud
Incheon	17	11	Soil dust	Anthropogenic	In-cloud
Taean	11	9.2	Marine + Soil dust	Anthropogenic	In-cloud
Jeju	4.5	8.0	Marine + Soil dust	Marine + Soil dust	In-cloud
Gwangju (Hg)	4.8	5.1	Anthropogenic	Anthropogenic	In-cloud
Gwangju (MeHg)	0.040	0.045	Anthropogenic	Anthropogenic	In-cloud

Thank you for your attention