Supplementary Material

**2021/03**
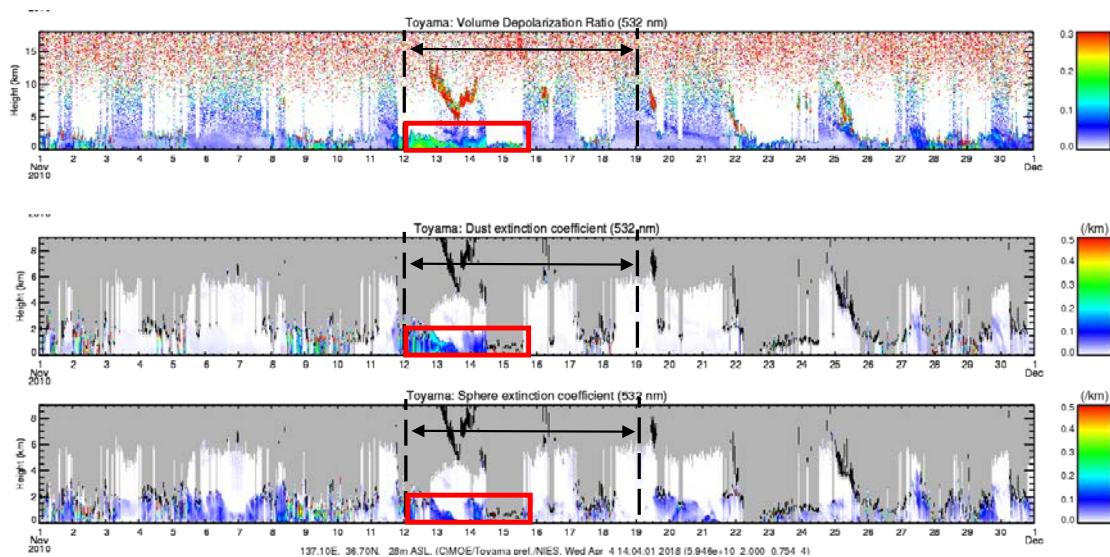
2010/03
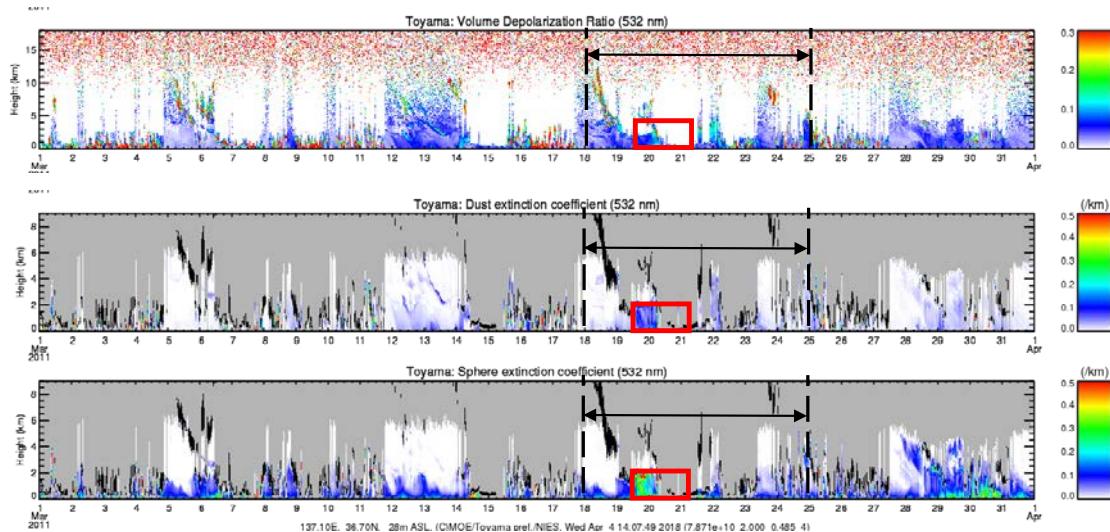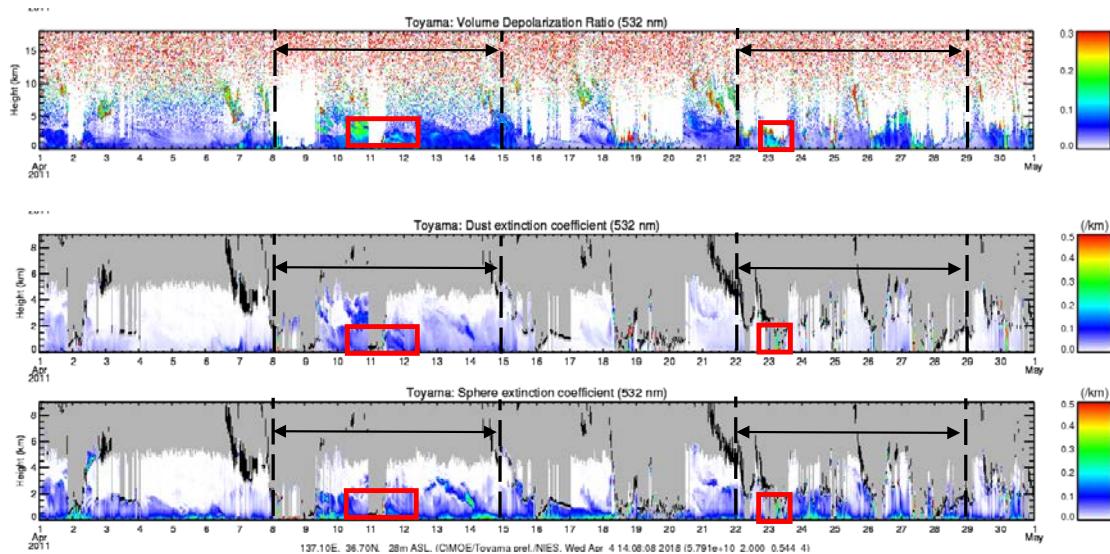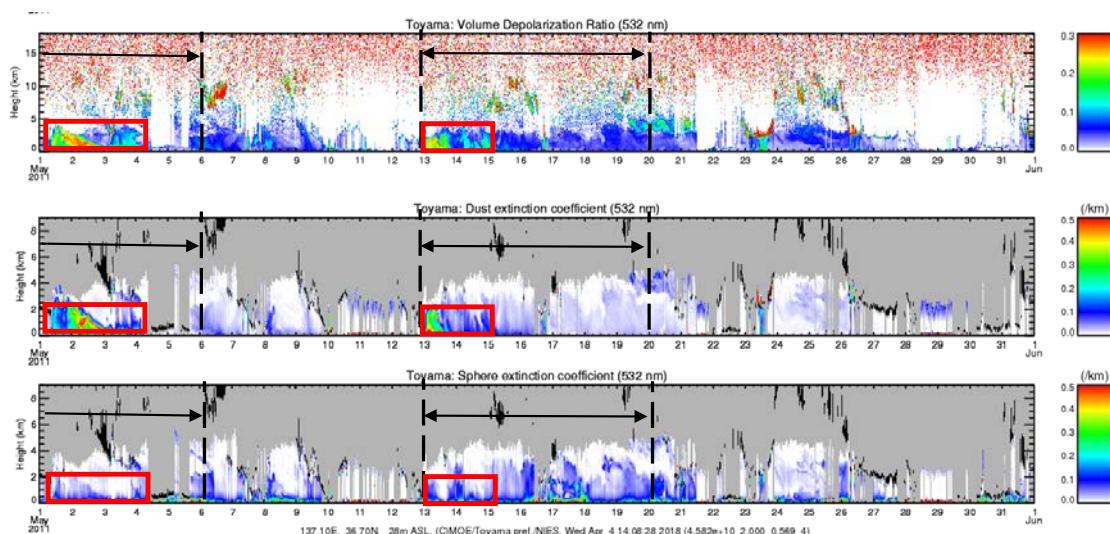
2010/04

2010/05

2010/11
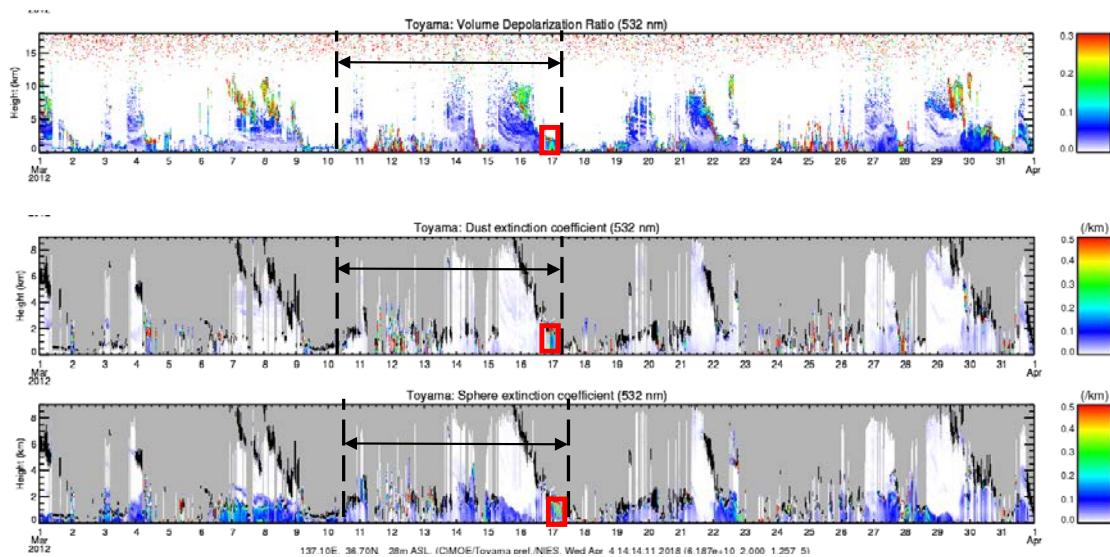
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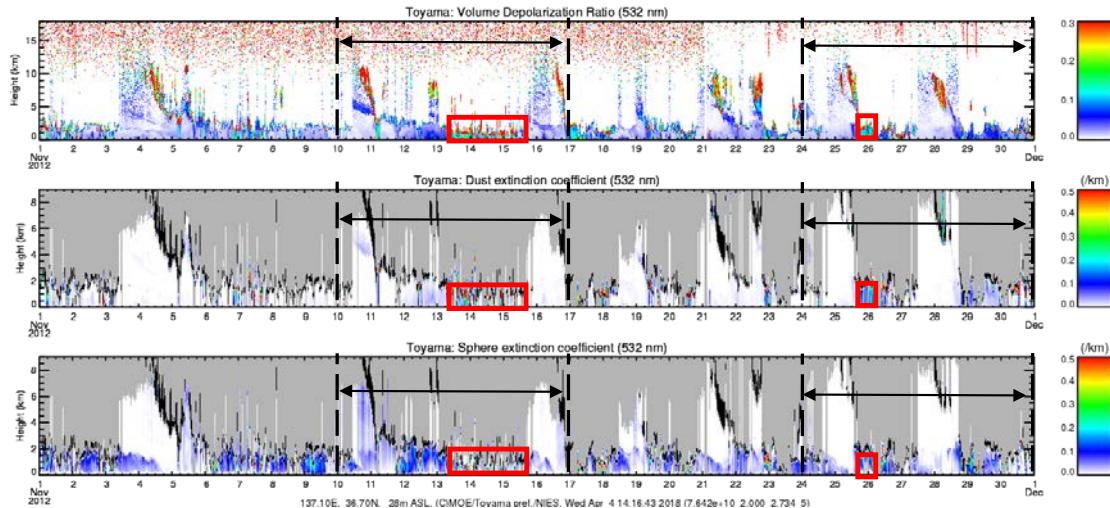
2011/04

2011/05
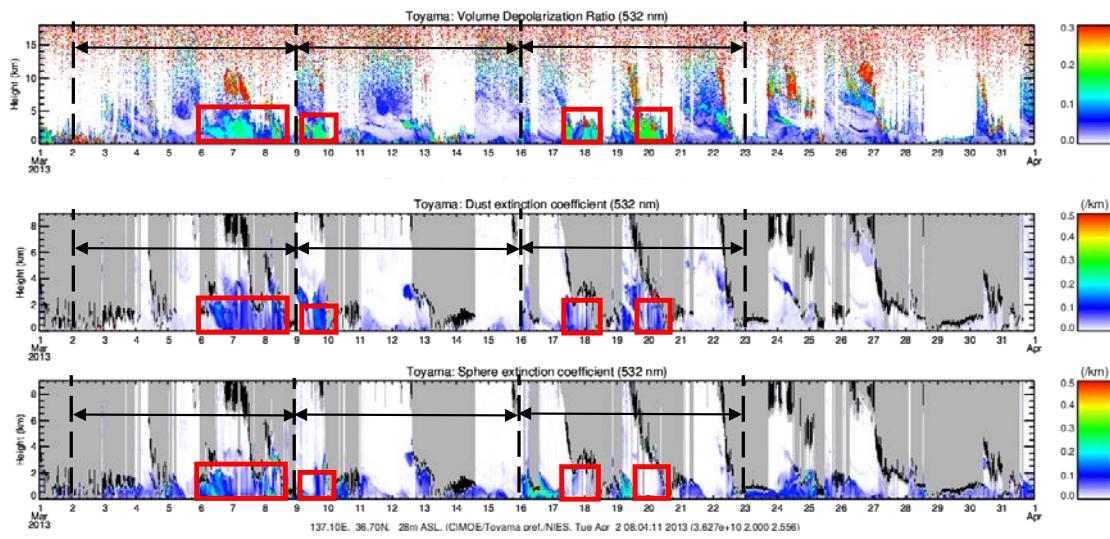
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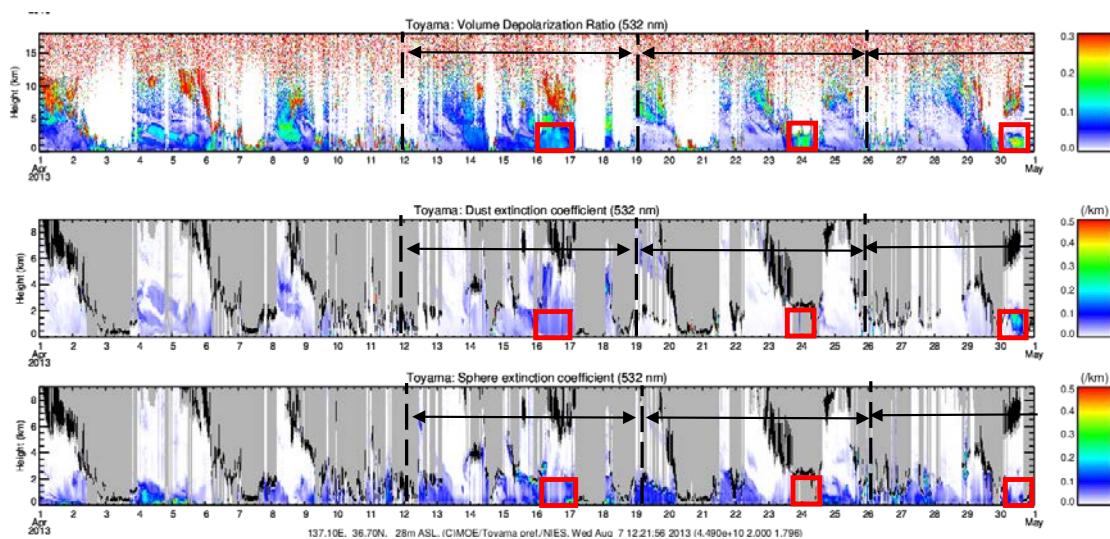
2012/11
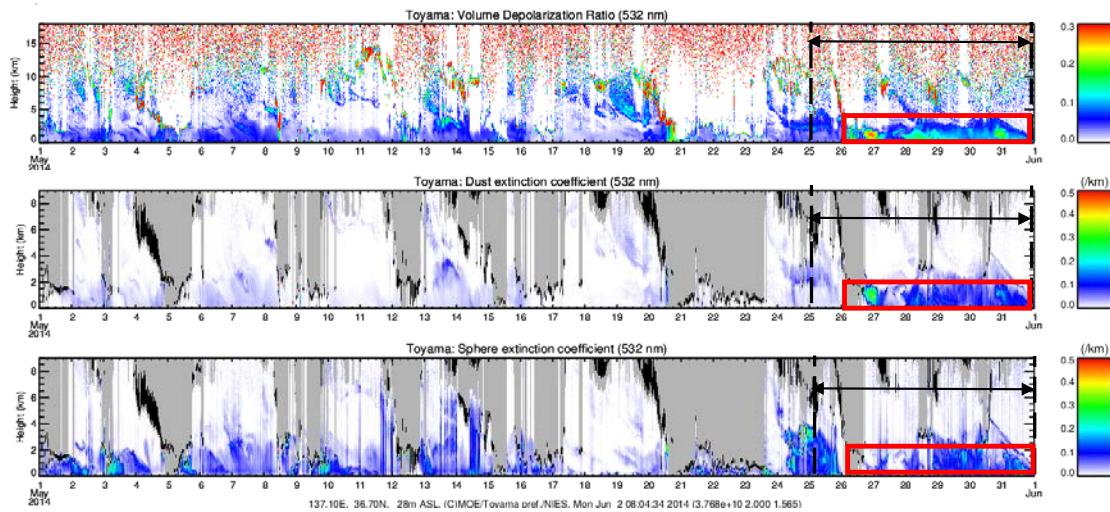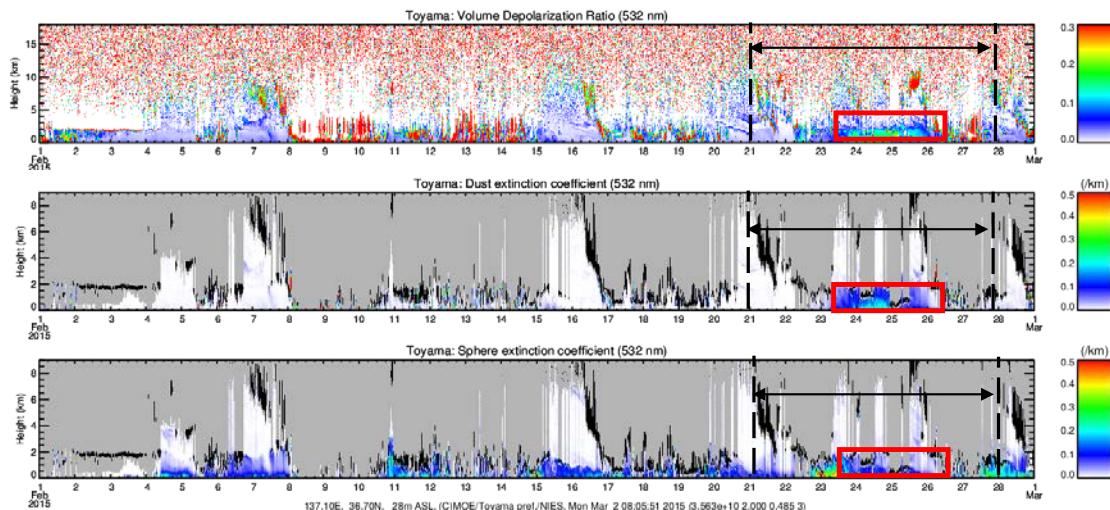
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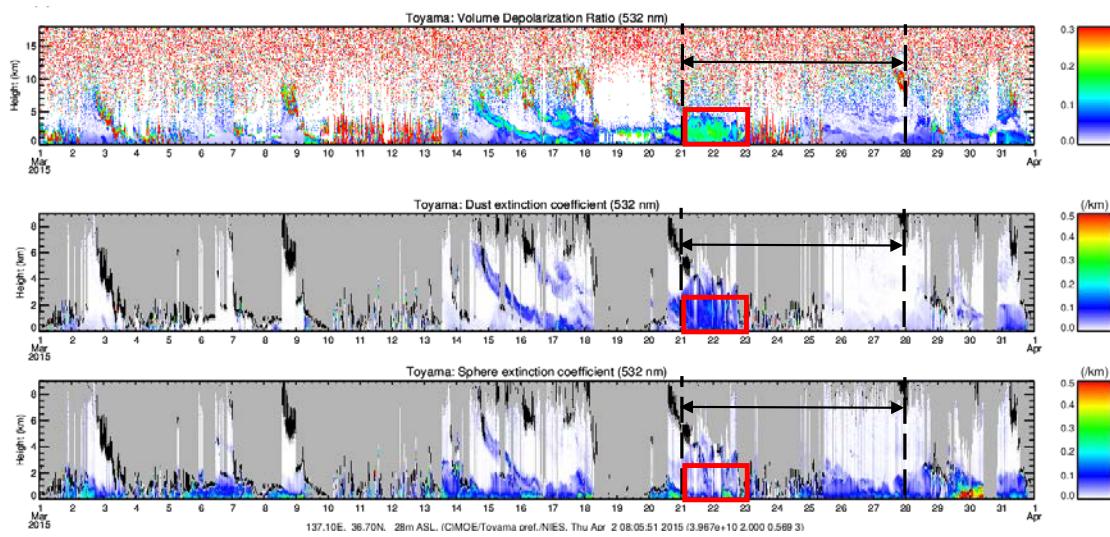
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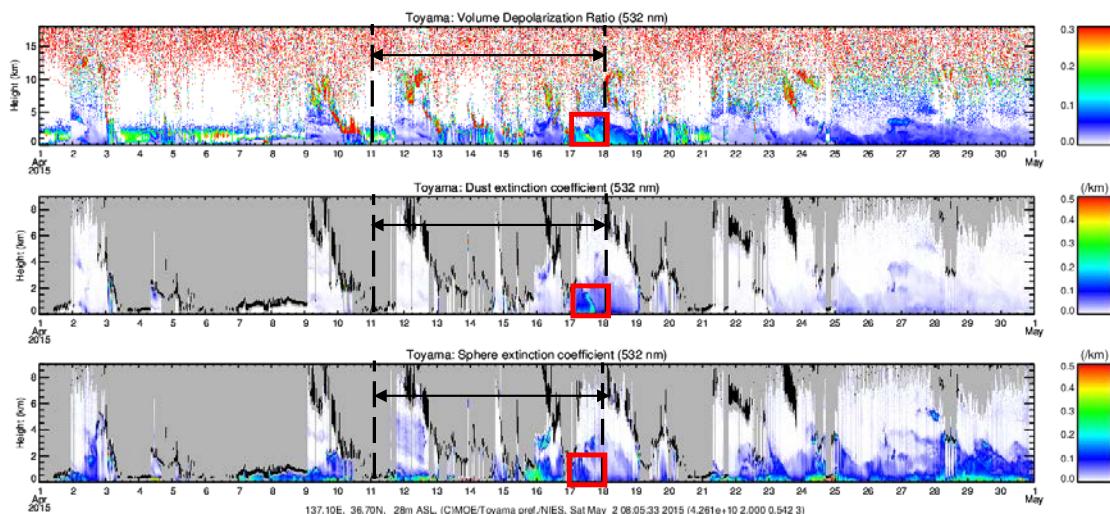
2014/05

2015/02
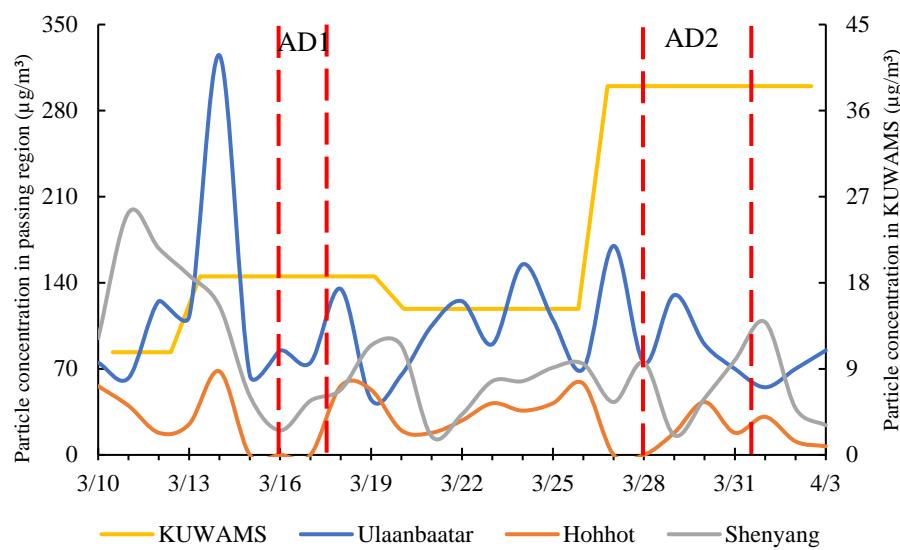
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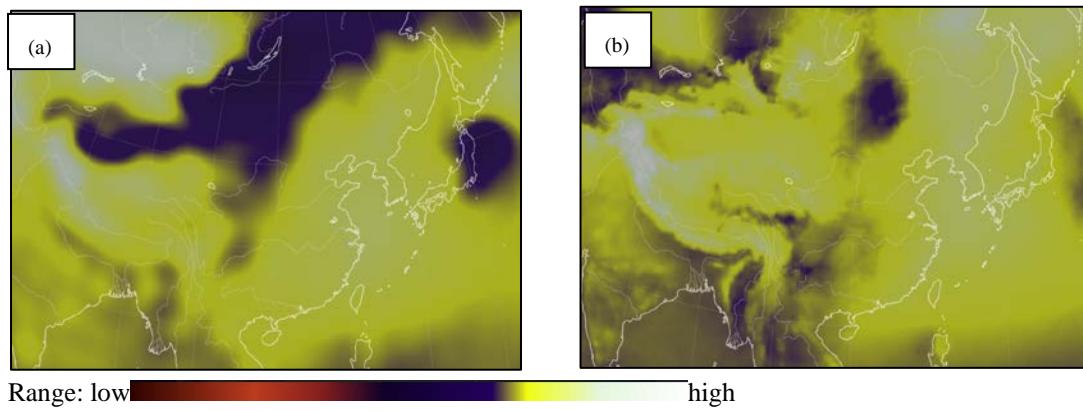
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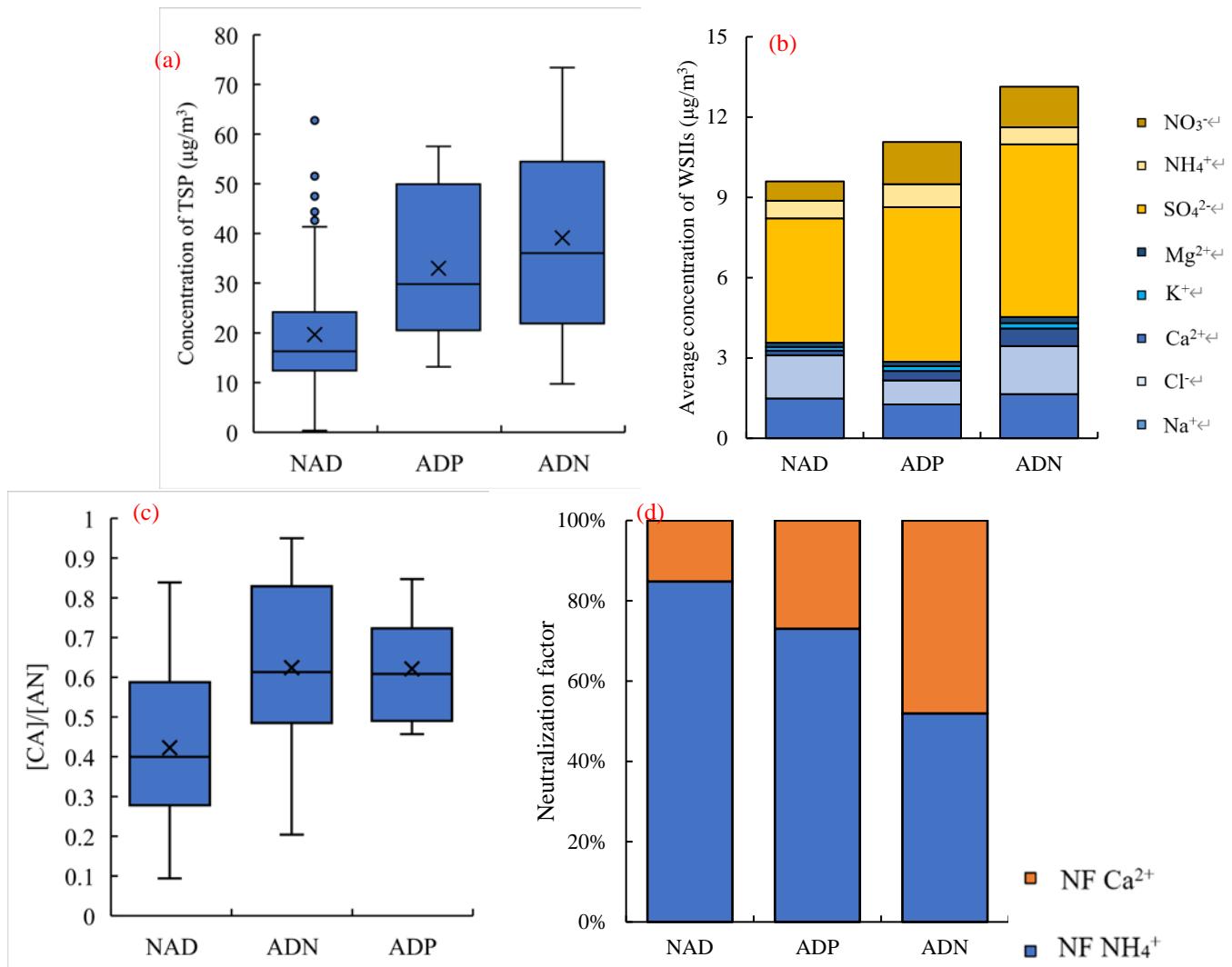
Figure S1. Lidar observation of attenuated backscatter coefficient (532 nm) during AD events in 2021 and from 2010 to 2015. Each AD event is marked in red block and the sampling period is marked with a black dotted line.
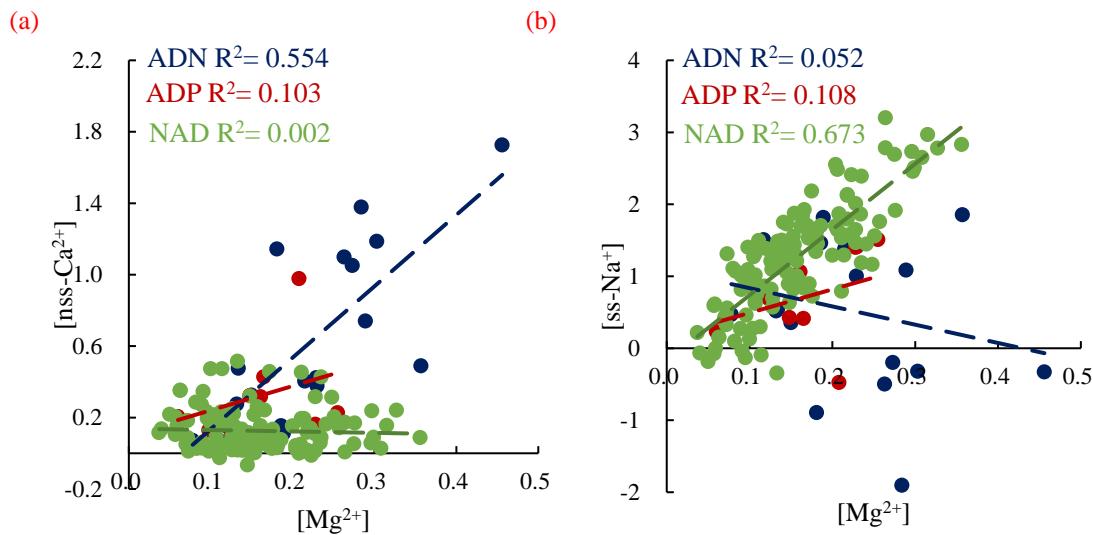
Figure S2. Daily concentration of PM$_{10}$ concentration in Ulaanbaatar, PM$_{2.5}$ in, Hohhot, Shenyang and TSP concentration in KUWAMS and from 03/10 to 04/03, 2021. The red dashed line represents for the time period of AD1 and AD2, respectively.
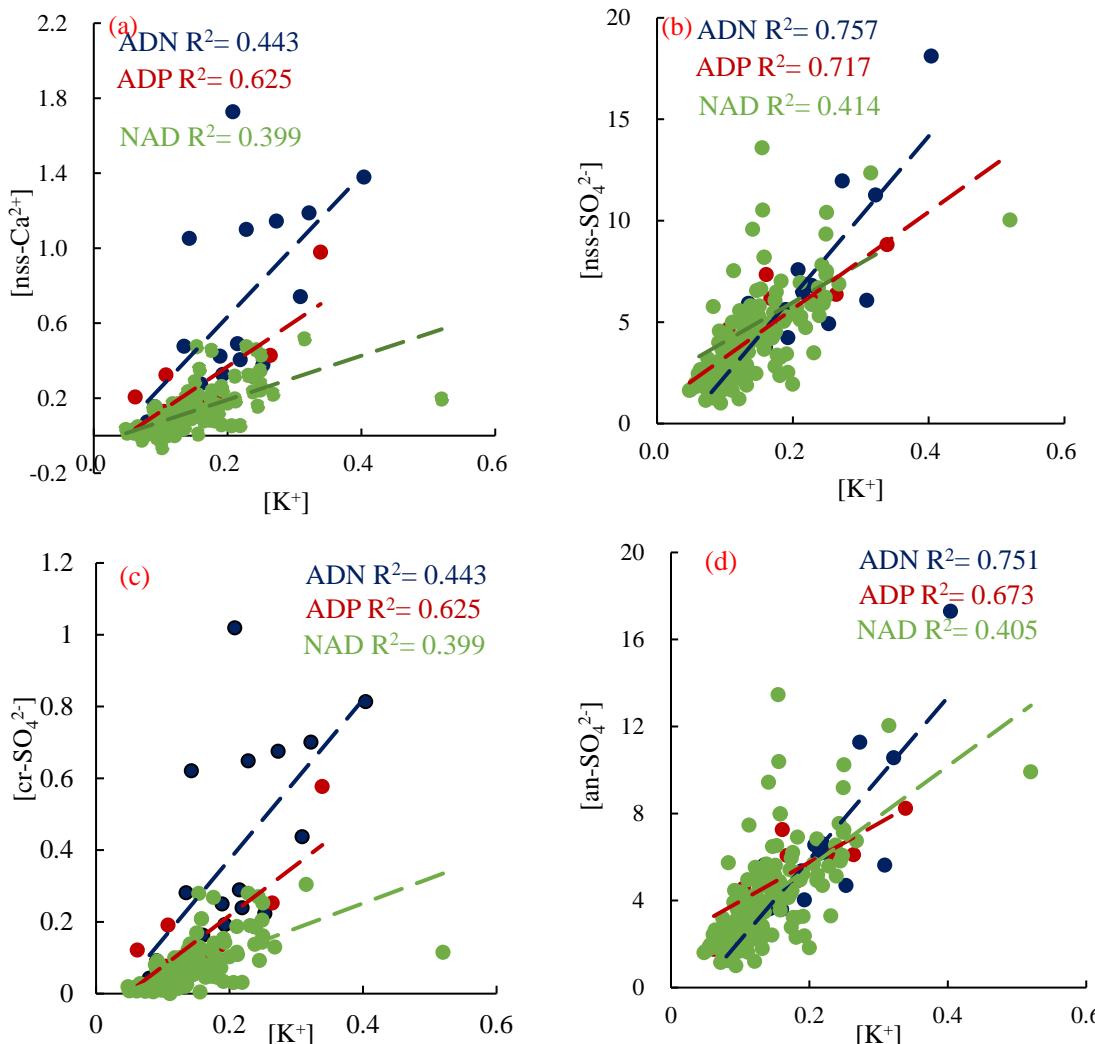
Figure S3. Sea-surface pressure on March 14 05:00 LT (a) and March 26 05:00 LT (b) during 2021.
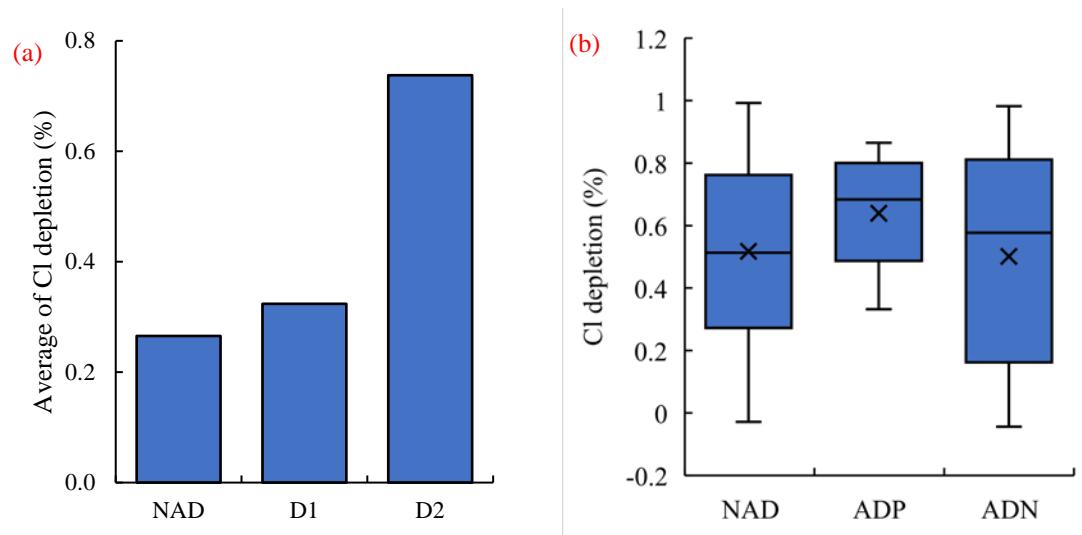
Figure S4. Concentration variation of TSP (**a**), WSIIs (**b**), [CA]/[AN] (**c**) and neutralization factor (**d**) in different types of AD during long-term observation from 2010-2015.
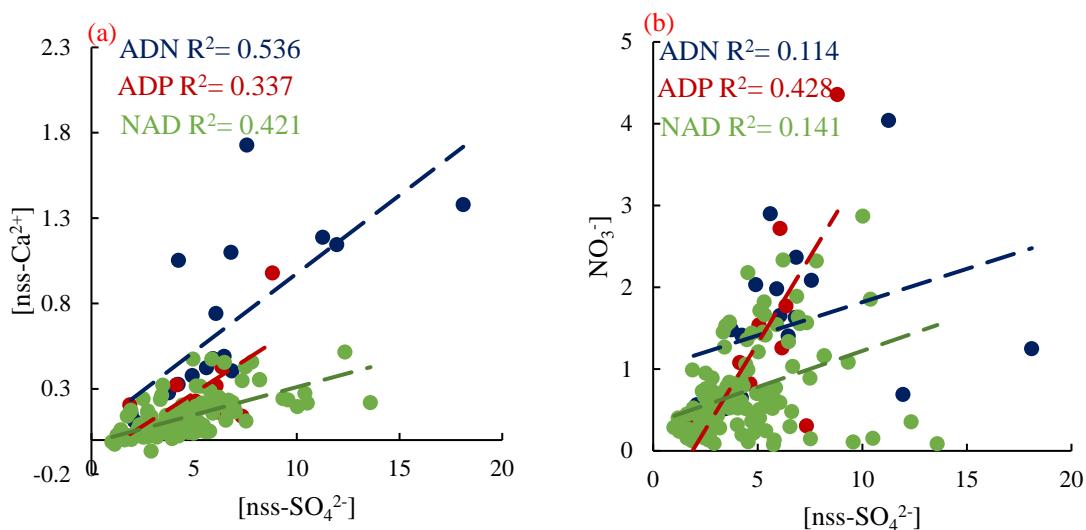
Figure S5. Linear fit regression of Mg^{2+} with nss-Ca^{2+} (**a**) and ss-Na^+ (**b**) during long-term observation from 2010 to 2015.
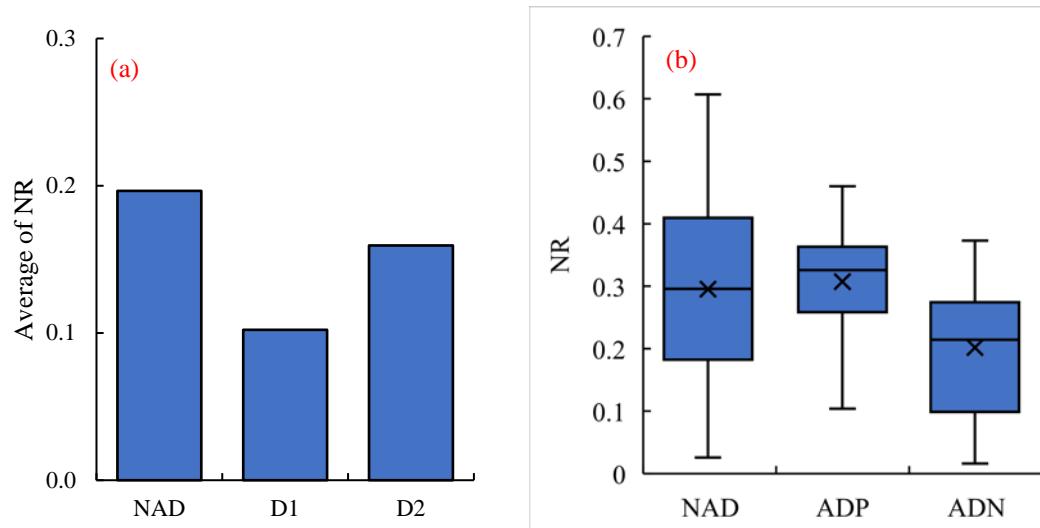
Figure S6. Linear fit regression of K^+ with nss-Ca^{2+} (**a**), nss-SO_4^{2-} (**b**), cr-SO_4^{2-} (**c**) and an-SO_4^{2-} (**d**) during long-term observation from 2010 to 2015.
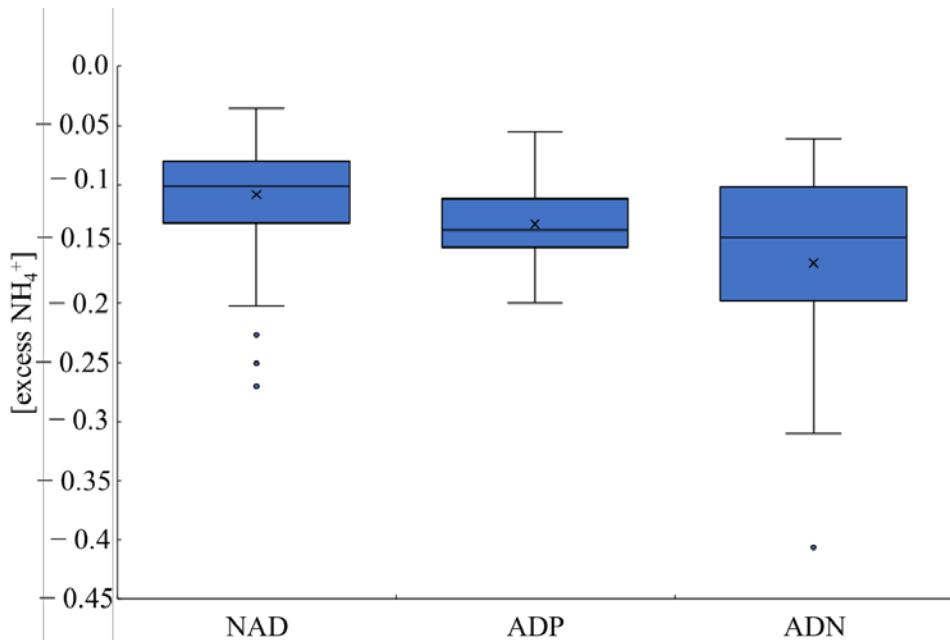
Figure S7. Cl depletion in different aerosol outflows during sampling in March 2021 (**a**) and long-term observation from 2010 to 2015 (**b**).

Figure S8. Linear regression of [nss-SO_4^{2-}] with [nss-Ca^{2+}] (**a**) and [NO_3^-] (**b**) during long-term observation from 2010 to 2015.

Figure S9. Neutralization ratio in different aerosol outflows during sampling period in 2021 (a) and long-term observation from 2010 to 2015 (**b**).

Figure S10. Concentration of [excess NH_4^+] with [NO_3^-] during long-term observation from 2010 to 2015.

Table S1. Concentration of water-soluble inorganic ions (WSIIs) and non-sea salt WSIIs during sampling period in 2021.

|	**NAD**	**NAD**	**AD1**	**NAD**	**AD2**
Na^+	0.54	1.27	1.06	0.84	0.46
SO_4^{2-}	0.74	1.48	2.08	2.67	1.91
NH_4^+	0.06	0.07	0.10	0.44	0.17
NO_3^-	0.30	0.50	0.85	2.07	1.21
Cl^-	0.81	2.33	1.29	0.54	0.22
Ca^{2+}	0.06	0.10	0.20	0.20	0.37
K^+	0.07	0.08	0.11	0.12	0.09
Mg^{2+}	0.06	0.14	0.13	0.11	0.08
$Nss-Na^+$	0.07	0.11	0.31	0.33	0.67
$ss-Na^+$	0.47	1.16	0.75	0.51	-0.20
$ss-Ca2^+$	0.02	0.04	0.03	0.02	-0.01
$Nss-Ca^{2+}$	0.04	0.06	0.18	0.18	0.37
$nss-K^+$	0.05	0.03	0.08	0.10	0.09
$nss-Mg^{2+}$	0.04	0.10	0.10	0.09	0.09
$nss-SO_4^{2-}$	0.63	1.18	1.89	2.55	1.96

Table S2. Time periods and type of AD from 2010 to 2015.

year	ADN	ADP
2010	03/14 12:00-03/15 15:00, 03/19 18:00-03/20 12:00, 04/02 9:00-04/04 00:00, 05/04 00: 00-05/06 00:00, 05/23 00:00-05/24 8:00, 11/12 00:00-11/15 12:00	04/16 6:00-04/16 18:00, 04/28 12:00-14/30 00:00
2011	05/01 10:00-05/04 6:00, 05/13 00:00-05/15 6:00	03/19 12:00- 03/21 12:00,04/10 12:00-04/12 12:00, 04/22 18:00-04/23 18:00
2012		03/16 21:00-03/17 6:00, 11/13 6:00-11/15 12:00, 11/25 18:00-11/27 00:00
2013	03/17 00:00-03/18 12:00, 03/19 18:00-03/20 18:00, 04/3000 00-05/01 00:00	03/06 18:00-03/10 00:00, 03/09 10:00-03/10 12:00, 04/16 00:00-04/17 00:00, 04/23 12:00- 04/24 12:00
2014		05/26 00:00-06/01 00:00
2015	02/23 00:00-02/26 00:00, 03/21 00:00-03/23 00:00, 04/17 6:00-04/19 00:00	