Seasonal Variation and Chemical Characteristics of Atmospheric Particles at Three Islands in the Taiwan Strait

Supplementary File

(13 papers, 5 Tables and 4 Figures include)

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S1-1 *Chemical Mass Balanced (CMB) Receptor Model*

The CMB receptor model uses the emission profiles of prominent sources to estimate their contribution to a specific receptor. It is assumed that the total concentration of a particular chemical species at the receptor is the linear summation of each individual contribution from various sources. The CMB receptor model uses the results of the least-square regression analysis of the aerosol chemical composition to resolve the most appropriate contributions of source apportionment. Therefore, this model consists of a least-square solution to a set of linear equations. This solution expresses each receptor concentration of a chemical species as a linear summation of the products of source profiles and source contributions. Source profiles (the fractional amount of each species in the emissions from each source type) and receptor concentrations, each with realistic uncertainty estimates, serve as the input data to the CMB receptor model. The model output consists of the contribution from each source type to the total ambient aerosol particle mass, as well as to individual chemical species concentration. The CMB8 model results are evaluated by using several fit indices, such as R^2 ($\geq$ 0.8), χ^2 ($\leq$ 4.0), T statistics ($\geq$ 2.0), and the percentage of mass accounted for 80-120%. The source profiles used in this study were reported by USEPA, Southern California Air Quality Study, and the researches studied the chemical composition of PM_{10} from local prominent sources in Taiwan. **Table S-2** summarizes the source profiles which were used in this case of PM_{10} in the Taiwan Strait.

S1-2 ***WRF Model Operation and Domain Setting***

For the model operation, the outermost domain (D1) covering the Matsu Islands has a center point at 26.16^{o}N, 119.94^{o}E with a horizontal grid of 40 km ×40 km and a grid spacing of 3 km. Domain 2 (D2) covering the Kimen Islands at a center point of 24.43^{o}N, 118.31^{o}E. It has a horizontal grid of 40 km ×40 km and a grid spacing of 3 km. Domain 3 (D3) is designed at the Penghu Islands at a center point of 23.56^{o}N, 119.56^{o}E and has a horizontal grid of 40 km ×40 km and a grid spacing of 3 km (**Table S-3)**. Additionally, for the vertical scale, there are 28 vertical sigma layers to all grid meshes from tile ground level to the top air pressure of 100 hPa. The initial meteorological fields and boundary conditions were obtained from NCEP FNL operational global analysis data with 1^{o}×1^{o} resolution degree grids.

Table Caption

Figure Caption.

Figure S-4 (a) Surface weather chart of April 11th, 2014 obtained from Taiwan Central Weather Bureau (TCWB).

Figure S-4(b) Surface weather chart of March 6th, 2013 obtained from Taiwan Central Weather Bureau (TCWB).

Figure S-4(c) Surface weather chart of October 8th, 2013 obtained from Taiwan Central Weather Bureau (TCWB).

Table S-1 Sampling location and environmental description of the island and coastal sampling sites in the Taiwan Strait.

Sites	Sampling Location	Latitude	Longitude	Altitude (m)	Site Description
FZ	Meihua	26°00’E	119°41’N	20	Township residential district
	Baison	26°13’E	119°39’N	15	Township residential district
	Huangqi	26°19’E	119°53’N	35	Up-wind hill area
MT	Nankan	26°10’E	120°55’N	40	Hillside at Nankan Island
	Peikan	26°13’E	120°58’N	30	Hillside at Peikan Island
	Donyin	26°21’E	120°29’N	35	Farmland and open area
XM	Xiamen	24°26'08"	118°05'25"	45	Heavy traffics and residential district
	Daderng	24°33'33"	118°19'49"	21	Township with a cargo harbor close to farmland
	Anhai	24°43'9"	118°28'11"	14	Residential, factory and traffic mixture area
	Jinjing	24°34'34"	118°36'10"	18	Residential, factory and traffic mixture area
	Xiangzhi	24°44'44"	118°44'58"	40	Township residential district
KM	Lieyu	24°25'50"	118°14'30"	34	Open agricultural field
	Jinding	24°26'53"	118°20'14"	30	Farmland and open area
	Jinsa	24°29'19"	118°24'43"	28	Township surrounding by open area
	Guchung	24°25'18"	118°26'19"	15	Farmland and open area
	Bortsuen	24°24'6"	118°18'45"	15	Farmland and open area
PH	Penghu Islands	23°33'41"	119°35'10"	25	Remote township coast

Table S-2 The mass concentration for different fraction of particles in the islands region..

Sampling Sites	Sampling Periods	Sampling Frequencies	Number of Samples
KM, XM	April 2008 to April 2009	2 days/month	750
	April 2009 to April 2010	3 days/month	
	Spring and Winter during 2008-2010	5 days/period× 3 periods	
MT, FZ	July 2011 to June 2012	2 days/month	204
	June 2012	5 days/periods × 2 periods	
PH	2008 to 2012	7 days/month	420

Table S-3 Source Profiles of PM_{10} used for chemical mass balance receptor modeling.

	Code	Source Profile	Researchers
SCT004	PBPRI1	Petroleum cracking Plant	U.S. EPA. 1991
SCT007	PP004	Industrial Boilers (Oil)	Cheng *et al.*, 2001
SCT008	PP005	Industrial Boilers (Coal)	Cheng *et al.*, 2001
SCT009	PETRO1	Petroleum Industry	U.S. EPA. 1991
SCT010	STEEL1	Steel Industry	Chiang *et al.*, 1993
SCT011	STEEL2	Coke Plant	Chiang *et al.*, 1993
SCT012	STEEL3	Sinter Plant	Chiang *et al.*, 1993
SCT013	STEEL4	Electric Arc Furnace	Yuan *et al.*, 2003
SCT020	CEMENT	Cement Industry	Chiang *et al.*, 1993
SCT023	VEHICLE2	Vehicular Exhausts	J.C Chow. 1991
SCT024	VEHICLE3	Diesel Exhausts	J.C Chow. 1991
SCT025	DUST1	Paved Road dust in South Taiwan	Cheng *et al.*, 1998
SCT026	DUST2	Paved Road dust in Central Taiwan	Cheng *et al.*, 1998
SCT027	DUST3	Paved Road dust in South Taiwan	Yuan *et al.*, 1991
SCT028	DUST4	Paved Road dust in Central Taiwan	Chiang *et al.*, 1993
SCT029	DUST5	Unpaved Road dust in Central Taiwan	Chiang *et al.*, 1993
SCT031	SOIL1	Soil Dusts	U.S. EPA. 1991
SCT033	MARIN1	Marin in Central Taiwan	Cheng *et al.*, 1998
SCT034	MARIN2	Marin in South Taiwan	Chen *et al.*, 1998
SCT035	VB001	Biomass Burning	Cheng *et al.*, 1999
SCT037	SO4	Secondary Sulfate	Wang *et al.*, 2006
SCT038	NO2	Secondary Nnitrate	Wang *et al.*, 2006
***SCT039**	**STONE**	***Stone processing industry**	***Li *et al.*, 2013b**
***SCT040**	**CEMENT2**	***Cement industries**	***Li *et al.*, 2013b**
***SCT041**	**CERM1**	***Ceramic plants**	***Li *et al.*, 2013b**
***SCT042**	**CERM2**	***Tile industries**	***Li *et al.*, 2013b**
***SCT043**	**COAL**	***Coal burning**	***Li *et al.*, 2013b**
***SCT044**	**COAA**	***Coal ash**	***Li *et al.*, 2013b**
***SCT045**	**SOIL2**	*** Fugitive dusts**	***Li *et al.*, 2013b**
***SCT046**	**VB002**	***Biomass burning**	***Li *et al.*, 2013b**
***SCT047**	**CONST**	***Construction dusts**	***Li *et al.*, 2013b**
***SCT048**	**DUST6**	***Road dusts**	***Li *et al.*, 2013b**

The source profiles used in this study were mainly obtained from the researcher's finding of the chemical composition of PM_{10} emitted from various emission sources. Only limited source profiles are referred from USEPA and Southern California Air Quality Study, and local emission source profiles.

Table S-4 Domain setting and selected configuration parameters for WRF model operation.

Type of setting	Domain 1 Matsu Islands (D1)	Domain 2 Kinmen Islands (D2)	Domain 3 Penghu Islands (D3)
Center Lat/lon	26.16N/119.94E	24.43N/118.31E	23.56N/119.56E
Horizontal grid (x,y)	40 km, 40 km	40 km, 40 km	40 km, 40 km
Grid spacing	3km	3 km	3km
Meteorological time step	20 s	20 s	20 s
Chemical time step	20 s	20 s	20 s
Grid mapping	Lambert	Lambert	Lambert
Microphysics	WSM3-class simple ice scheme		
Cumulus physics option	None		
Subgrid convective transport	Turned on		

Table S-5 The mass concentrations and chemical composition of PM_{10} sampled at the island and coastal sampling sites in the Taiwan Strait.

	Seasons	PM_{10}	F^-	Cl^-	NO_3^-	SO_4^{2-}	Na^+	NH_4^+	K^+	Mg^{2+}	Ca^{2+}	Mg	K	Ca	Mn	Fe	Zn	Al	Pb	Ni	EC	OC
KM	spring	82.83±25.20	0.11±0.08	2.20±0.93	8.75±3.30	13.90±5.13	1.60±0.66	6.97±2.79	0.59±0.26	0.40±0.27	0.70±0.39	1.05±0.40	1.20±0.80	1.81±0.89	0.02±0.00	1.03±0.39	0.40±0.28	0.94±0.51	0.35±0.19	0.07±0.01	6.73±2.75	9.63±2.97
	summer	79.59±41.13	0.15±0.11	1.67±0.38	7.80±4.58	15.53±9.28	1.21±0.31	7.62±4.46	0.51±0.32	0.36±0.33	0.71±0.58	0.65±0.63	1.12±0.55	1.54±1.16	0.04±0.05	1.45±0.80	0.20±0.30	1.56±1.03	0.34±0.60	0.15±0.08	6.11±2.46	8.83±3.30
	fall	83.64±32.96	0.04±0.06	1.09±0.65	8.30±4.06	15.18±6.13	0.83±0.48	7.77±3.56	0.78±0.54	0.23±0.17	0.56±0.37	0.58±0.53	0.81±0.65	2.45±1.56	0.00±0.01	1.35±1.17	0.89±0.84	1.72±1.75	0.32±0.37	0.12±0.15	6.39±2.75	8.79±10.59
	winter	88.59±27.10	0.03±0.07	1.20±0.32	8.08±3.56	15.95±5.35	0.90±1.49	8.26±2.75	0.49±0.33	0.27±0.22	0.39±0.15	0.59±0.45	1.57±1.75	1.19±0.81	0.11±0.08	1.09±0.73	0.55±0.52	1.40±1.24	0.75±0.81	0.27±0.14	5.44±1.35	9.44±3.90
XM	spring	120.00±57.15	0.25±0.26	2.45±0.76	12.49±5.63	18.76±7.88	1.75±0.54	9.97±4.12	0.86±0.36	0.52±0.29	0.99±0.56	0.72±0.61	2.31±0.73	2.03±0.91	0.19±0.07	1.56±0.53	0.77±0.66	1.65±0.92	0.69±0.35	0.16±0.04	7.41±3.47	11.64±6.23
	summer	94.83±37.35	0.28±0.41	2.22±0.76	8.78±4.24	16.75±7.58	1.79±0.84	7.64±4.03	0.75±0.38	0.56±0.29	0.79±0.75	0.58±0.60	1.22±0.74	2.05±1.67	0.05±0.06	1.83±1.43	0.32±0.41	2.11±2.31	0.77±1.24	0.14±0.19	6.27±2.90	10.59±4.14
	fall	120.24±53.22	0.31±0.43	3.40±2.3	10.47±3.66	21.42±9.78	2.49±1.13	9.66±4.71	1.39±0.85	0.60±0.31	1.12±0.67	0.68±0.45	1.42±0.73	2.81±1.39	0.09±0.08	1.93±1.30	0.69±0.55	2.76±2.90	0.19±0.11	0.15±0.14	8.60±4.44	13.01±6.54
	winter	116.68±57.31	0.19±0.29	3.79±2.96	10.86±6.64	18.01±8.35	2.21±1.07	9.94±5.36	0.52±0.32	0.42±0.25	0.56±0.54	0.74±0.41	1.32±0.65	3.00±1.84	0.10±0.08	2.06±1.08	0.66±0.67	3.35±3.42	0.25±0.14	0.19±0.17	7.36±3.75	11.52±5.54
MT	spring	70.56±22.67	0.06±0.02	2.80±1.26	6.94±1.92	10.99±3.05	1.85±0.78	3.59±0.94	0.37±0.30	0.22±0.15	1.81±1.03	0.56±0.17	0.38±0.24	1.44±0.62	0.05±0.03	0.95±0.38	0.11±0.13	1.65±0.53	0.12±0.12	0.02±0.02	1.82±0.64	5.27±1.28
	summer	27.06±10.04	0.03±0.03	1.61±0.70	1.07±0.58	3.91±1.26	1.14±0.49	0.94±0.36	0.33±0.11	0.05±0.02	0.32±0.15	0.30±0.14	0.40±0.12	0.57±0.19	0.00±0.01	0.66±0.25	0.14±0.09	1.01±0.39	0.03±0.09	ND	0.62±0.25	2.72±1.07
	fall	43.86±21.92	0.06±0.05	1.83±0.87	2.96±2.29	6.63±3.66	1.31±0.66	1.90±1.20	0.27±0.16	0.26±0.19	0.87±0.75	0.44±0.24	0.35±0.17	1.21±0.85	0.02±0.02	1.09±0.60	0.06±0.07	1.91±1.01	0.03±0.04	0.02±0.03	0.92±0.65	2.84±1.71
	winter	54.94±25.32	0.05±0.03	1.64±0.42	3.98±3.16	8.35±4.54	1.23±0.30	2.42±1.50	0.28±0.14	0.35±0.29	0.88±0.93	0.55±0.37	0.51±0.24	1.20±0.93	0.05±0.03	1.18±1.02	0.09±0.05	2.18±1.55	0.11±0.12	0.05±0.08	1.81±1.39	4.49±2.91
FZ	spring	98.28±26.87	0.06±0.03	2.91±0.73	8.32±1.25	15.42±3.94	2.04±0.48	4.10±0.51	0.55±0.18	0.19±0.16	2.01±1.23	0.55±0.19	0.46±0.16	2.47±0.59	0.03±0.02	1.95±0.25	0.09±0.14	2.92±0.66	0.27±0.15	0.04±0.02	2.68±0.79	7.25±1.73
	summer	30.41±8.34	0.04±0.04	1.20±0.36	1.37±0.71	4.72±1.21	0.83±0.28	1.20±0.36	0.35±0.16	0.06±0.03	0.38±0.24	0.28±0.09	0.44±0.08	0.68±0.29	0.05±0.10	0.64±0.15	0.17±0.11	0.92±0.2	0.12±0.20	ND	0.69±0.31	2.85±1.20
	fall	64.01±23.27	0.09±0.07	2.77±0.07	4.36±2.77	10.81±4.84	1.97±0.67	2.91±1.40	0.41±0.18	0.35±0.28	1.35±0.94	0.54±0.29	0.51±0.21	1.82±1.01	0.04±0.06	1.38±0.62	0.26±0.29	2.59±1.50	0.10±0.13	0.03±0.03	1.67±1.07	4.87±2.59
	winter	74.00±30.45	0.05±0.02	2.54±0.57	6.66±4.65	12.29±6.65	1.84±0.40	3.69±2.06	0.39±2.06	0.59±0.67	1.37±1.58	0.87±0.80	0.65±0.39	1.69±1.45	0.07±0.08	1.66±1.21	0.10±0.07	2.91±1.57	0.09±0.06	0.07±0.07	3.01±2.00	6.99±3.34
PH	spring	69.24±43.27	ND	5.27±2.83	5.11±4.80	13.08±8.16	3.44±1.92	3.34±2.54	1.83±1.22	1.08±0.72	2.15±2.02	0.50±0.52	0.57±0.71	0.13±0.19	0.02±0.02	0.57±0.87	0.06±0.06	1.98±2.00	0.04±0.04	0.01±0.01	1.06±0.57	3.20±1.06
	summer	42.60±10.95	ND	4.35±1.21	1.99±0.93	7.61±1.41	2.92±0.84	2.63±0.58	0.40±0.11	0.29±0.10	0.31±0.17	0.04±0.05	0.08±0.06	0.49±0.25	ND	0.06±0.03	0.01±0.01	0.17±0.26	ND	ND	0.82±0.35	3.43±1.11
	fall	33.91±7.544	ND	3.04±0.62	1.92±0.59	4.47±1.70	2.07±0.43	1.46±0.46	0.50±0.13	0.36±0.09	0.32±0.09	0.11±0.10	0.13±0.07	0.17±0.19	ND	0.08±0.04	0.02±0.01	0.17±0.18	0.01±0.01	ND	0.58±0.34	1.72±0.60
	winter	45.85±26.39	ND	5.38±2.68	1.75±0.64	8.44±3.56	3.89±1.88	2.81±1.69	0.42±0.29	0.49±0.32	1.03±0.61	0.40±0.17	0.52±0.48	0.36±0.37	0.01±0.01	0.30±0.27	0.09±0.10	0.68±0.80	0.04±0.05	0.01±0.01	1.10±0.95	3.12±1.67

Unit : $\mu g/m^3$; ND: not detectable

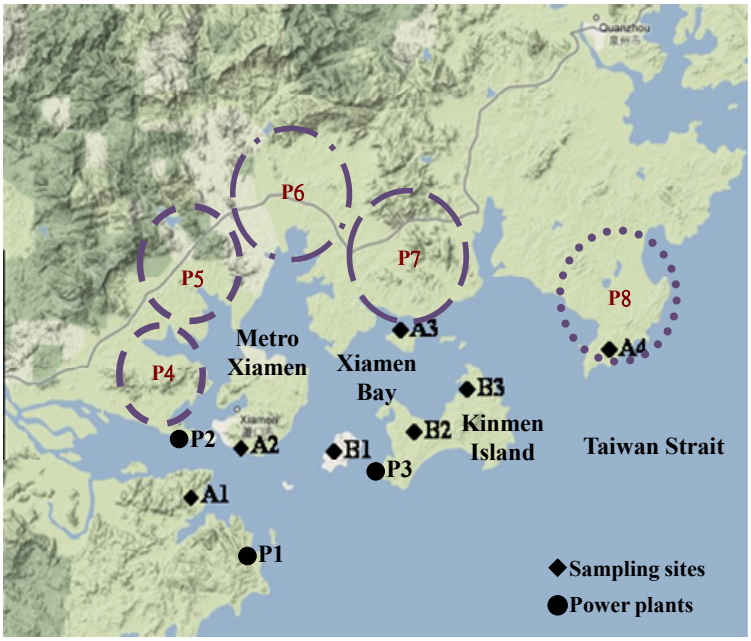

Figure S-1 Location of PM_{10} sampling sites and major industrial complexes surrounding the Kinmen-Xiamen Airshed. (P1–P3: power plant; P1: Houshi power plant; P2: Songyu power plant; P3: Tashan power plant; P4: petroleum refinery; P5: petrochemical and mechanical industries; P6: light industries; P7: ceramics and stone process industries; P8: textile industry). (Li et al., 2013a,b)

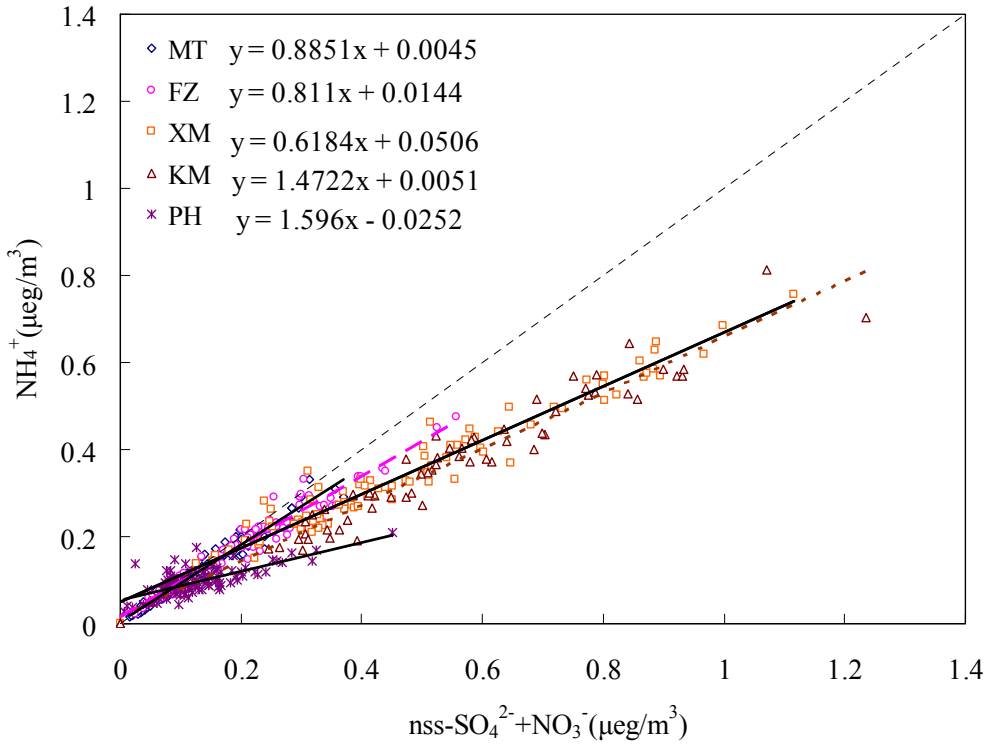

Figure S-2 The neutralization ratios (NR) of PM_{10} at the island and coastal sampling sites in the Taiwan Strait.

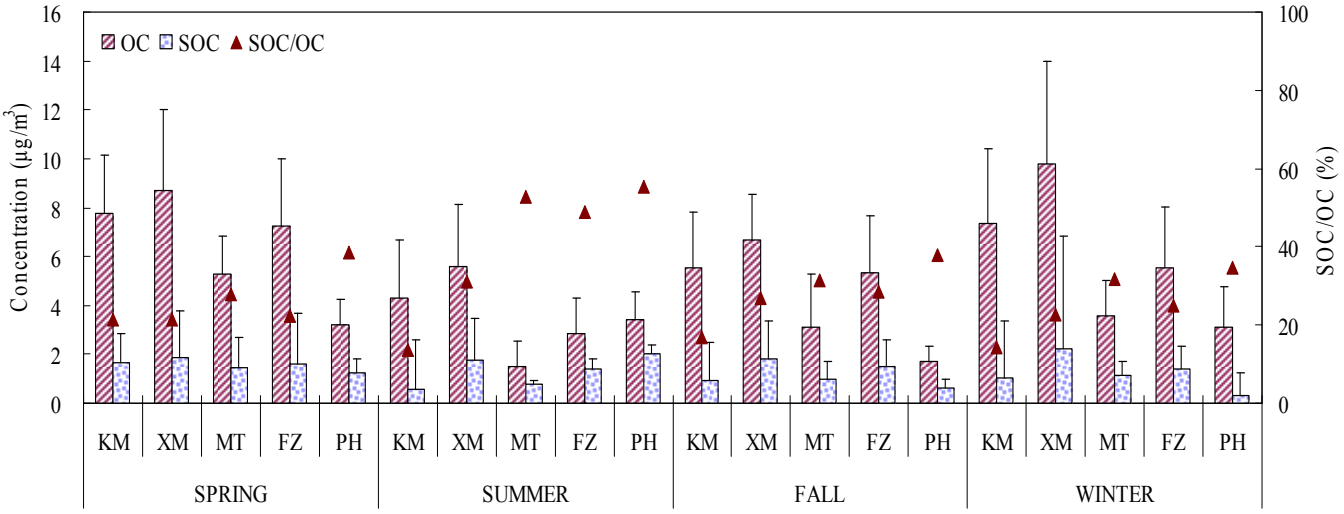

Figure S-3 Tempospatial variation of estimated secondary OC concentrations and their contribution to total OC.

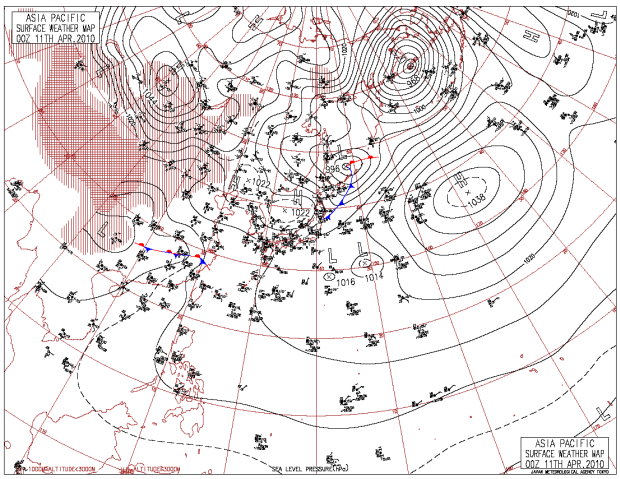

Figure S-4 (a) Surface weather chart of April 11th, 2014 obtained from Taiwan Central Weather Bureau (TCWB).

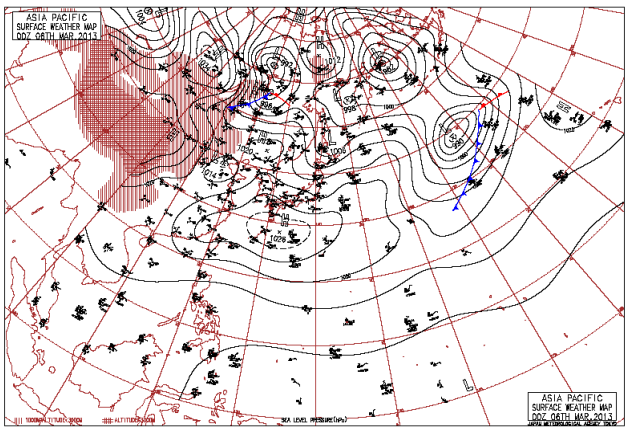

Figure S-4 (b) Surface weather chart of March 6th, 2013 obtained from Taiwan Central Weather Bureau (TCWB)..

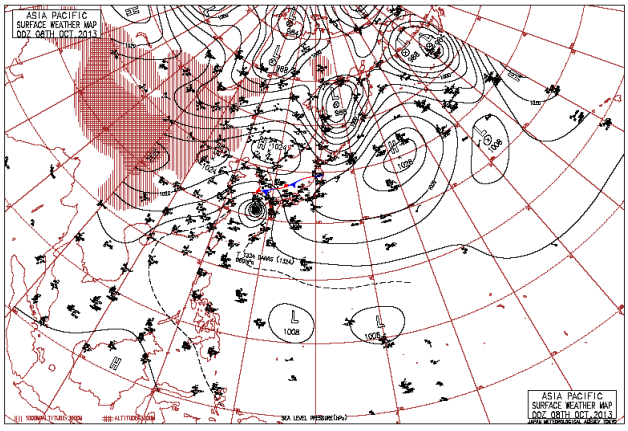

Figure S-4 (c) Surface weather chart of October 8th, 2013 obtained from Taiwan Central Weather Bureau (TCWB).