Supplementary Materials:

Spatiotemporal Variations and Health Implications of Hazardous Air Pollutants in Ulsan, a Multi-Industrial City in Korea

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Table S1. Emissions (kg/year) of selected airborne toxic chemicals from four industrial districts in Ulsan, 2010.

Toxic chemical	Ulsan Total	Onsan District	Yeocheon District	Mipo District	Yangjeong District
		Non-Ferrous Metal Industry	Petrochemical Industry	Ship Building Industry	Automobile Industry
Xylenes	5,109,600	193,708	354,325	4,041,726	519,842
Ethylbenzene	680,517	11,700	29,980	457,201	181,637
Toluene	460,835	74,099	99,581	109,837	177,317
Methanol	248,457	144,341	103,269	363	483
Isopropyl alcohol	228,782	54,217	18,914	145,747	9,904
Ethyl acetate	149,635	30,351	3,305	388	115,590
Ethylene	119,802	1,864	32,279	85,659	0
Methyl ethyl ketone	96,178	42,180	38,374	89	15,536
n-Hexane	88,898	35,295	53,603	0	0
Benzene	68,657	23,406	45,251	0	0
Propylene	65,211	1,366	63,845	0	0
Butane	55,234	4,971	50,263	0	0
Acrylonitrile	45,461	18,941	26,519	0	0
Styrene	41,005	198	36,732	292	3,783
Cresols	34,906	34,867	39	0	0
Propylene oxide	33,065	0	33,065	0	0
Methyl tert-butyl ether	30,491	24,336	6,155	0	0
Vinyl chloride	28,596	0	28,596	0	0
Dichloromethane	27,106	4,236	22,860	10	0
Cyclohexane	26,418	1,550	24,868	0	0
1,3-Butadiene	13,259	98	13,161	0	0
Vinyl acetate	11,696	7,116	4,553	27	0
Chloroform	8,986	444	8,541	0	0
1,2-Dichloroethane	7,499	326	7,173	0	0
Phenol	7,314	6,819	346	149	0
Epichlorohydrin	6,369	505	4,808	1,056	0
Ethylene oxide	6,329	77	6,252	0	0
Carbon tetrachloride	5,952	0	5,952	0	0
N,N-Dimethylformamide	4,694	1,257	3,437	0	0
Methyl chloride	4,035	2,897	1,138	0	0
Formaldehyde	3,364	1,858	1,205	71	231
Trichloroethylene	3,226	2,294	932	0	0
Lead compounds	2,505	2,009	0	0	496
Naphthalene	2,289	2,230	59	0	0
Di(2-ethylhexyl)phthalate	1,330	570	751	9	0
Manganese compounds	951	939	11	1	0
Tetrachloroethylene	640	1	639	0	0
Acetaldehyde	247	0	247	0	0
2-Methoxy ethanol	189	167	22	0	0
Aniline	27	7	20	0	0
Arsenic compounds	22	22	0	0	0
Cadmium compounds	21	18	3	0	0
Chromium compounds	10	10	0	0	1
2-Ethoxyethaol	4	4	0	0	0
Cobalt compounds	3	0	2	1	0
Nickel compounds	1	1	0	0	0
Butyl benzyl phthalate	0	0	0	0	0
Selenium compounds	0	0	0	0	0
Total amount	7,739,667	740,645	1,131,257	4,842,627	1,025,139

Note: data were extracted from the Korean PRTR database in 2010 [20].

Table S2. Toxicity values applied to the vapor phase HAPs.

HAPs	Weight of Evidence		Carcinogenic Unit Risk (μg/m³)⁻¹		Noncarcinogenic Benchmark Concentration (mg/m³)	
	IARC	IRIS	Value	Source	Value	Source
Vinyl chloride	1	CH	8.8E−06	IRIS[a)]	1.0E−01	IRIS
1,3-Butadiene	1	CH	3.0E−05	IRIS	2.0E−03	IRIS
Bromomethane	3	D	-	-	5.0E−03	IRIS
Chloroethane	3	-	-	-	1.0E+01	IRIS
2-Propanol	3	-	-	-	2.0E−01	PPRTVs [b)]
Acrylonitrile	2B	B1	6.8E−05	IRIS	2.0E−03	IRIS
1,1-Dichloroethene	2B	SE	-	-	2.0E−01	IRIS
Dichloromethane	2A	LH	1.0E−08	IRIS	6.0E−01	IRIS
Freon113	-	-	-	-	5.0E+00	PPRTVs
Carbon disulfide	-	-	-	-	7.0E−01	IRIS
Methyl tert-butyl ether	3	C	2.6E−07	OEHHA[c)]	3.0E+00	IRIS
1,1-Dichloroethane	-	-	1.6E−06	OEHHA	5.0E−01	HEAST [d)]
Vinyl acetate	2B	-	-	-	2.0E−01	IRIS
Ethyl acetate	-	-	-	-	7.0E−02	PPRTVs
Hexane	-	InI	-	-	7.0E−01	IRIS
Chloroform	2B	LH	2.3E−05	IRIS	9.9E−02	ATSDR [e)]
2-Methoxyethanol	-	-	-	-	2.0E−02	IRIS
Tetrahydrofuran	2B	SE	-	-	2.0E+00	IRIS
1,2-Dichloroethane	2B	LH	2.6E−05	IRIS	2.5E+00	ATSDR
1,1,1-Trichloroethane	3	InI	-	-	5.0E+00	IRIS
Benzene	1	CH	7.8E−06	IRIS	3.0E−02	IRIS
Carbon tetrachloride	2B	LH	6.0E−06	IRIS	1.0E−01	IRIS
Cyclohexane	-	-	-	-	6.0E+00	IRIS
1,2-Dichloropropane	1	B2	1.0E−05	OEHHA	4.0E−03	IRIS
1,4-Dioxane	2B	LH	5.0E−06	IRIS	3.0E−02	IRIS
Bromodichloromethane	2B	-	3.7E−05	OEHHA	-	-
Trichloroethylene	1	CH	4.1E−06	IRIS	2.0E−03	IRIS
2-Ethoxyethanol	-	-	-	-	2.0E−01	IRIS
Epichlorohydrin	2A	B2	1.2E−06	IRIS	1.0E−03	IRIS
Heptane	-	InI	-	-	-	-
4-Methyl−2-pentanone	2B	InI	-	-	3.0E+00	IRIS
1,1,2-Trichloroethane	3	C	1.6E−05	IRIS	-	-
N,*N*-Dimethylformamide	2A	-	-	-	3.0E−02	IRIS
Toluene	3	InI	-	-	5.0E+00	IRIS
2-Hexanone	2B	-	-	-	3.0E−02	IRIS
1,2-Dibromoethane	2A	LH	6.0E−04	IRIS	9.0E−03	IRIS
Tetrachloroethylene	2A	LH	2.6E−07	IRIS	4.0E−02	IRIS
Chlorobenzene	-	D	-	-	1.0E+00	OEHHA
Ethylbenzene	2B	D	2.5E−06	OEHHA	1.0E+00	IRIS
m,*p*,*o*-Xylenes	3	InI	-	-	1.0E−01	IRIS
2-Ethoxyethylacetate	-	-	-	-	3.0E−01	OEHHA
Bromoform	3	B2	1.1E−06	IRIS	-	-
Styrene	2B	-	-	-	1.0E+00	IRIS
1,1,2,2-Tetrachloroethane	2B	LH	5.8E−05	OEHHA	-	-
Phenol	3	InI	-	-	2.0E−01	OEHHA
Aniline	3	B2	1.6E−06	OEHHA	1.0E−03	IRIS
1,2,4-Trimethylbenzene	-	-	-	-	7.0E−03	PPRTVs
Benzyl chloride	2A	B2	4.9E−05	OEHHA	1.0E−03	PPRTVs
1,4-Dichlorobenzene	2B	-	1.1E−05	OEHHA	8.0E−01	IRIS
Nitrobenzene	2B	LH	4.0E−05	IRIS	9.0E−03	IRIS
1,2,4-Trichlorobenzene	-	D	-	-	2.0E−01	HEAST
Naphthalene	2B	C	3.4E−05	OEHHA	3.0E−03	IRIS
Hexachloro−1,3-butadiene	3	C	2.2E−05	IRIS	-	-
Formaldehyde	1	B1	1.3E−05	IRIS	10.0E−03	ATSDR
Acetaldehyde	1	B2	2.2E−06	IRIS	9.0E−03	IRIS
Acetone	-	InI	-	-	3.1E+01	ATSDR
Acrolein	3	InI	-	-	2.0E−05	IRIS
Propionaldehyde	-	InI	-	-	8.0E−03	IRIS
2-Butanone (MEK)	-	InI	-	-	5.0E+00	IRIS

a) IRIS: Integrated risk information system [47]; b) PPRTVs: Provisional peer-reviewed toxicity values [52]; c) OEHHA: Air chemical database provided by the Office of Environmental Health Hazard Assessment [48]; d) HEAST: Health effects assessment summary tables [50]; e) ATSDR: Toxicological profiles from the Agency for Toxic Substances and Disease Registry [51].

Table S3. Toxicity data applied to the particulate HAPs.

HAPs	Weight of Evidence		Carcinogenic Unit Risk $(\mu g/m^3)^{-1}$		Noncarcinogenic Benchmark Concentration (mg/m^3)	
	IARC	IRIS	Value	Source	Value	Source
Naphthalene	2B	C	-	-	3.0E−03	IRIS[a)]
Biphenyl	-	SE	-	-	4.0E−04	PPRTVs[b)]
Acenaphthylene	-	D	-	-	-	-
Acenaphthene	3	D	-	-	-	-
Fluorene	3	D	-	-	-	-
Dibenzothiophene	3	-	-	-	-	-
Phenanthrene	3	D	-	-	-	-
Anthracene	3	D	-	-	-	-
4H-cyclopenta[d,e,f]phenanthrene	-	-	-	-	-	-
Fluoranthene	3	D	8.7E−05	WHO[c)]	-	-
Pyrene	3	D	-	-	-	-
Benzo[c]phenanthrene	2B	-	-	-	-	-
Benzo[g,h,i]fluoranthene	3	-	-	-	-	-
Cyclopenta[c,d]pyrene	2A	-	8.7E−03	WHO[c)]	-	-
Benz[a]anthracene	2B	B2	8.7E−03	WHO[c)]	-	-
Triphenylene	3	-	-	-	-	-
Chrysene	2B	B2	8.7E−04	WHO[c)]	-	-
Benzo[b]fluoranthene	2B	B2	8.7E−03	WHO[c)]	-	-
Benzo[j]fluoranthene	2B	-	8.7E−03	WHO[c)]	-	-
Benzo[k]fluoranthene	2B	B2	8.7E−03	WHO[c)]	-	-
Benzo[a]fluoranthene	3	-	-	-	-	-
Benzo[e]pyrene	3	-	-	-	-	-
Benzo[a]pyrene	1	CH	8.7E−02	WHO[d)]	2.0E−06	IRIS
Perylene	3	-	-	-	-	-
Dibenz[a,j]anthracene	3	-	-	-	-	-
Indeno[1,2,3-c,d]pyrene	2B	B2	8.7E−03	WHO[c)]	-	-
Dibenz[a,h]anthracene	2A	B2	8.7E−02	WHO[c)]	-	-
Dibenz[a,c]anthracene	3	-	8.7E−03	WHO[c)]	-	-
Benzo[b]chrysene	3	-	-	-	-	-
Picene	3	-	-	-	-	-
Benzo[g,h,i]perylene	3	D	-	-	-	-
Anthanthrene	3	-	8.7E−03	WHO[c)]	-	-
Dibenzo[b,k]fluoranthene	-	-	-	-	-	-
Dibenzo[a,h]pyrene	2B	-	8.7E−02	WHO[c)]	-	-
Coronene	3	-	-	-	-	-
Dibenzo[a,e]pyrene	3	-	8.7E−02	WHO[c)]	-	-
Dimethyl phthalate	-	D	-	-	-	-
Diethyl phthalate	-	D	-	-	-	-
Dibutyl phthalate	-	D	-	-	-	-
Butyl benzyl phthalate	3	C	-	-	-	-
Di(2-ethylhexyl)phthalate	2B	B2	2.4E−06	OEHHA[e)]	-	-
Dioctyl phthalate	-	-	-	-	-	-
Arsenic (As)	1	A	4.3E−03	IRIS	1.5E−05	OEHHA
Cadmium (Cd)	1	B1	1.8E−03	IRIS	1.0E−05	ATSDR[f)]
Cobalt (Co)	2B	-	9.0E−03	PPRTV	1.0E−04	ATSDR
Chromium (Cr(VI))	1	CH	1.2E−02	IRIS	1.0E−04	IRIS
Manganese (Mn)	-	D	-	-	3.0E−04	ATSDR
Nickel (Ni)	1	A	2.4E−04	IRIS	9.0E−05	ATSDR
Lead (Pb)	2B	B2	1.2E−05	OEHHA	1.5E−04	IRIS
Selenium (Se)	3	D	-	-	2.0E−02	OEHHA
Vanadium (V)	-	-	-	-	1.0E−04	ATSDR

a) IRIS: Integrated risk information system [47]; b) PPRTV: Provisional peer-reviewed toxicity values [52]; c) The unit risk for each PAH was calculated using a relative potential factor with respect to the unit risk of benzo[a]pyrene [49] (See Table S3 for details); d) WHO: Guidelines for air quality [49]; e) OEHHA: Air chemical database provided by the Office of Environmental Health Hazard Assessment [48]; f) ATSDR: Toxicological profiles from the Agency for Toxic Substances and Disease Registry [51].

Table S4. Sources of relative potency factors (RPF) for the PAHs and adopted values.

PAH	Weight of Evidence		Nisbet and LaGoy [53]	USEPA [54]	Malcom and Dobson [55]	WHO [49]		CAL EPA [56]	This Study [b]	Remark
	IRIS	IARC				Range (Mean)	Represen-Tative RPF[a]			
Fluoranthene	D	3	0.001	-	0.001	0.001–0.01 (0.005)	0.001	-	0.001	Tier II
Cyclopenta[c,d]pyrene	-	2A	-	-	0.1	0.012–0.1 (0.056)	0.1	-	0.1	Tier II
Benz[a]anthracene	B2	2B	0.1	0.1	0.1	0.014–0.145 (0.080)	0.1	0.1	0.1	Tier II
Chrysene	B2	2B	0.01	0.001	0.01	0.001–0.1 (0.050)	0.01	0.01	0.01	Tier II
Benzo[b]fluoranthene	B2	2B	0.1	0.1	0.1	0.1–0.141 (0.120)	0.1	0.1	0.1	Tier I
Benzo[j]fluoranthene	-	2B	-	-	-	0.045–0.1 (0.073)	0.1	0.1	0.1	Tier I
Benzo[k]fluoranthene	B2	2B	0.1	0.01	0.1	0.01–0.1 (0.055)	0.1	0.1	0.1	Tier II
Benzo[a]pyrene	CH	1	1	1	1	1	1	1	1	Tier I
Indeno[1,2,3-c,d]pyrene	B2	2B	0.1	0.1	0.1	0.067–0.232 (0.150)	0.1	0.1	0.1	Tier I
Dibenz[a,h]anthracene	B2	2A	1	1	1	0.89–5 (2.945)	1	0.4	1	Tier I
Dibenz[a,c]anthracene	-	3	-	-	0.1	0.1	0.1	-	0.1	Tier I
Anthanthrene	-	3	-	-	-	0.28–0.32 (0.30)	0.1	-	0.1	Tier I
Dibenzo[a,h]pyrene	-	2B	-	-	-	1–1.2 (1.1)	1	10	1	Tier I
Dibenzo[a,e]pyrene	-	3	-	-	-	-	-	1	1	Tier III

a) In this study, the representative RPF was determined based on the following rounding scheme:

0.51−5.0 = 1.0; 0.051−0.50 = 0.1; 0.0051−0.050 = 0.01, 0.00051−0.0050 = 0.001, referring to the USEPA approach to determine a single estimate of relative potency from individual estimates comprising a range [54].

b) This study adopted an RPF for each PAH according to the following rule:

Tier I: The RPF values estimated by WHO were preferred over values from other sources

Tier II: When the WHO values overlapped between two ranges (e.g., fluoranthene, cyclopenta[c,d]pyrene, chrysene, benz[a]anthracene, benzo[k]fluoranthene), a value close to the more common value available from other sources was chosen.

Tier III: When no WHO value was available, and only one value was available from the USEPA or California EPA, the available value was taken.

Table S5. Carcinogenic risk assessment for HAPs in industrial and residential areas of Ulsan.

HAP	Benchmark Concentration [a]		Ambient Concentration				Cancer risk Estimate			
			Industrial area		Residential area		Industrial Area		Residential Area	
	Value	Ref.	Mean	Max.	Mean	Max	Mean	Max	Mean	Max
Vapor phase HAPs (μg/m³)										
1,3-Butadiene	3.33E−02	[47]	0.18	9.23	0.01	1.84	5.5E−06	2.8E−04	3.2E−07	5.5E−05
Acrylonitrile	1.47E−02	[47]	0.07	2.02	0.00	0.61	4.7E−06	1.4E−04	1.3E−07	4.1E−05
Dichloromethane	1.00E+02	[47]	0.11	4.48	0.06	3.06	1.1E−09	4.5E−08	6.1E−10	3.1E−08
Methyl tert-butyl ether	3.85E+00	[48]	0.99	34.45	0.88	20.00	2.6E−07	9.0E−06	2.3E−07	5.2E−06
Chloroform	4.35E−02	[47]	0.06	2.32	0.01	0.63	1.4E−06	5.3E−05	1.4E−07	1.4E−05
1,2-Dichloroethane	3.85E−02	[47]	0.50	23.69	0.04	1.46	1.3E−05	6.2E−04	1.1E−06	3.8E−05
Benzene	1.28E−01	[47]	4.96	78.79	1.06	11.38	3.9E−05	6.1E−04	8.3E−06	8.9E−05
Carbon tetrachloride	1.67E−01	[47]	0.51	26.11	0.37	1.01	3.1E−06	1.6E−04	2.2E−06	6.1E−06
1,2-Dichloropropane	1.00E−01	[48]	0.05	5.74	0.01	0.85	5.3E−07	5.7E−05	6.4E−08	8.5E−06
Trichloroethylene	2.44E−01	[47]	1.85	60.23	0.23	1.79	7.6E−06	2.5E−04	9.6E−07	7.3E−06
Tetrachloroethylene	3.85E+00	[47]	0.62	32.41	0.03	1.69	1.6E−07	8.4E−06	8.3E−09	4.4E−07
Ethylbenzene	4.00E−01	[48]	5.09	63.86	1.52	27.77	1.3E−05	1.6E−04	3.8E−06	6.9E−05
Naphthalene	2.94E−02	[48]	0.10	0.71	0.19	1.95	3.3E−06	2.4E−05	6.4E−06	6.6E−05
Formaldehyde	7.69E−02	[47]	4.44	29.20	4.31	30.52	5.8E−05	3.8E−04	5.6E−05	4.0E−04
Acetaldehyde	4.55E−01	[47]	3.85	21.86	3.04	26.95	8.5E−06	4.8E−05	6.7E−06	5.9E−05
Particulate HAPs (ng/m³)										
Fluoranthene	1.15E+01	*	0.75	5.17	0.91	3.32	6.5E−08	4.5E−07	7.9E−08	2.9E−07
Cyclopenta[c,d]pyrene	1.15E−01	*	0.22	0.80	0.21	0.60	1.9E−06	6.9E−06	1.8E−06	5.2E−06
Benz[a]anthracene	1.15E−01	*	0.31	1.18	0.34	1.19	2.7E−06	1.0E−05	3.0E−06	1.0E−05
Chrysene	1.15E+00	*	0.47	1.70	0.49	1.45	4.1E−07	1.5E−06	4.2E−07	1.3E−06
Benzo[b+j]]fluoranthene	1.15E−01	*	0.74	2.80	0.76	2.42	6.4E−06	2.4E−05	6.6E−06	2.2E−05
Benzo[k]fluoranthene	1.15E−01	*	0.18	0.72	0.18	0.65	1.6E−06	6.3E−06	1.5E−06	5.7E−06
Benzo[a]pyrene	1.15E−02	[49]	0.31	1.43	0.34	1.57	2.7E−05	1.2E−04	3.0E−05	1.4E−04
Indeno[1,2,3-c,d]pyrene	1.15E−01	*	0.28	1.20	0.26	1.16	2.5E−06	1.0E−05	2.3E−06	1.0E−05
Dibenz[a,h]anthracene	1.15E−02	*	0.03	0.14	0.02	0.13	2.2E−06	1.2E−05	1.9E−06	1.1E−05
Dibenz[a,c]anthracene	1.15E−01	*	0.03	0.14	0.02	0.13	2.2E−07	1.2E−06	1.9E−07	1.1E−06
Anthanthrene	1.15E−01	*	0.07	0.46	0.07	0.51	6.3E−07	4.0E−06	6.1E−07	4.4E−06
Dibenz[a,h]pyrene	1.15E−02	*	0.04	0.28	0.03	0.25	3.5E−06	2.4E−05	2.6E−06	2.2E−05
Di(2-ethylhexyl)phthalate	4.17E+02	[48]	58.72	222.95	80.69	243.67	1.4E−07	5.4E−07	1.9E−07	5.8E−07
Arsenic (As)	2.33E−01	[47]	46.74	654.43	4.42	37.75	2.0E−04	2.8E−03	1.9E−05	1.6E−04
Cadmium (Cd)	5.56E−01	[47]	9.36	60.14	1.51	11.12	1.7E−05	1.1E−04	2.7E−06	2.0E−05
Cobalt (Co)	1.11E−01	[52]	2.16	5.71	1.19	5.56	1.9E−05	5.1E−05	1.1E−05	5.0E−05
Chromium (Cr(VI))	8.33E−02	[47]	0.88	5.34	0.21	2.42	1.1E−05	6.4E−05	2.5E−06	2.9E−05
Nickel (Ni)	4.17E+00	[47]	40.58	296.27	6.03	16.81	9.7E−06	7.1E−05	1.4E−06	4.0E−06
Lead (Pb)	8.33E+01	[48]	317.62	1772.66	41.27	336.77	3.8E−06	2.1E−05	5.0E−07	4.0E−06
Cumulative cancer risk							4.7E−04		1.7E−04	

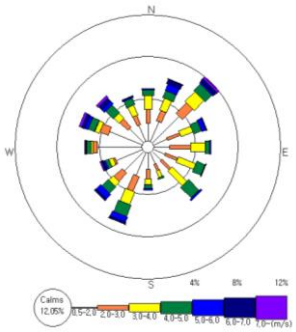
a) The carcinogenic benchmark level is defined as the concentration of a HAP that poses a 1 x 10^{-6} lifetime excess cancer risk.; * The unit risk was calculated using a relative potential factor with respect to the unit risk of benzo[a]pyrene estimated by WHO (see Table S3 for details)

Table S6. Noncarcinogenic risk assessment for HAPs in industrial and residential areas of Ulsan.

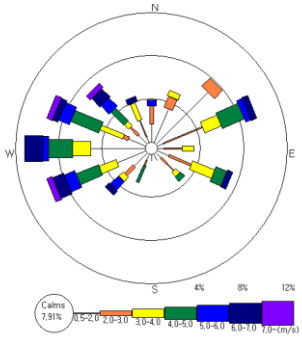
HAP	Benchmark Concentration [a]		Ambient Concentration				Hazard quotient (HQ) Estimate			
			Industrial Area		Residential Area		Industrial Area		Residential Area	
	Value	Ref.	Mean	Max	Mean	Max	Mean	Max	Mean	Max
Vapor phase HAPs (μg/m³)										
1,3-Butadiene	2.0E+00	[47]	0.18	9.23	0.01	1.84	9.1E−02	4.6E+00	5.3E−03	9.2E−01
2-Propanol	2.0E+02	[52]	0.16	5.88	0.04	1.72	7.9E−04	2.9E−02	1.8E−04	8.6E−03
Acrylonitrile	2.0E+00	[47]	0.07	2.02	0.00	0.61	3.5E−02	1.0E+00	9.5E−04	3.0E−01
Dichloromethane	6.0E+02	[47]	0.11	4.48	0.06	3.06	1.9E−04	7.5E−03	1.0E−04	5.1E−03
Carbon disulfide	7.0E+02	[47]	0.02	0.45	0.01	0.46	2.4E−05	6.4E−04	1.8E−05	6.6E−04
Methyl tert-butyl ether	3.0E+03	[47]	0.99	34.45	0.88	20.00	3.3E−04	1.1E−02	2.9E−04	6.7E−03
Vinyl acetate	2.0E+02	[47]	2.28	27.36	1.25	15.49	1.1E−02	1.4E−01	6.2E−03	7.7E−02
Ethyl acetate	7.0E+01	[52]	1.54	30.50	0.94	12.46	2.2E−02	4.4E−01	1.3E−02	1.8E−01
Hexane	7.0E+02	[47]	178.71	2082.66	3.57	254.40	2.6E−01	3.0E+00	5.1E−03	3.6E−01
Chloroform	9.8E+01	[51]	0.06	2.32	0.01	0.63	6.4E−04	2.4E−02	6.3E−05	6.4E−03
Tetrahydrofuran	2.0E+03	[47]	0.10	6.30	0.00	0.41	4.8E−05	3.2E−03	1.9E−06	2.1E−04
1,2-Dichloroethane	2.4E+03	[51]	0.50	23.69	0.04	1.46	2.1E−04	9.9E−03	1.8E−05	6.1E−04
1,1,1-Trichloroethane	5.0E+03	[47]	0.04	2.57	0.01	0.26	8.2E−06	5.1E−04	2.7E−06	5.2E−05
Benzene	3.0E+01	[47]	4.96	78.79	1.06	11.38	1.7E−01	2.6E+00	3.5E−02	3.8E−01
Carbon tetrachloride	1.0E+02	[47]	0.51	26.11	0.37	1.01	5.1E−03	2.6E−01	3.7E−03	1.0E−02
Cyclohexane	6.0E+03	[47]	3.36	51.42	0.50	4.74	5.6E−04	8.6E−03	8.3E−05	7.9E−04
1,2-Dichloropropane	4.0E+00	[47]	0.05	5.74	0.01	0.85	1.3E−02	1.4E+00	1.6E−03	2.1E−01
Trichloroethylene	2.0E+00	[47]	1.85	60.23	0.23	1.79	9.2E−01	3.0E+01	1.2E−01	9.0E−01
4-Methyl−2-pentanone	3.0E+03	[47]	1.12	14.55	0.41	51.77	3.7E−04	4.9E−03	1.4E−04	1.7E−02
N,N-Dimethylformamide	3.0E+01	[47]	0.83	13.56	0.05	2.98	2.8E−02	4.5E−01	1.8E−03	9.9E−02
Toluene	5.0E+03	[47]	14.16	180.65	6.10	144.20	2.8E−03	3.6E−02	1.2E−03	2.9E−02
Tetrachloroethylene	4.0E+01	[47]	0.62	32.41	0.03	1.69	1.5E−02	8.1E−01	8.0E−04	4.2E−02
Chlorobenzene	1.0E+03	[48]	0.18	15.49	0.00	0.34	1.8E−04	1.5E−02	3.6E−06	3.4E−04
Ethylbenzene	1.0E+03	[47]	5.09	63.86	1.52	27.77	5.1E−03	6.4E−02	1.5E−03	2.8E−02
o,m,p-Xylenes	1.0E+02	[47]	11.91	125.90	3.85	76.34	1.2E−01	1.3E+00	3.8E−02	7.6E−01
Styrene	1.0E+03	[47]	36.27	1230.97	0.20	7.66	3.6E−02	1.2E+00	2.0E−04	7.7E−03
Phenol	2.0E+02	[48]	0.05	1.34	0.06	3.65	2.6E−04	6.7E−03	2.8E−04	1.8E−02
1,2,4-Trimethylbenzene	7.0E+00	[52]	1.04	8.66	0.44	7.14	1.5E−01	1.2E+00	6.3E−02	1.0E+00
Naphthalene (VOC)	3.0E+00	[47]	0.10	0.71	0.19	1.95	3.3E−02	2.4E−01	6.2E−02	6.5E−01
Formaldehyde	1.0E+01	[51]	4.44	29.20	4.31	30.52	4.5E−01	2.9E+00	4.3E−01	3.1E+00
Acetaldehyde	9.0E+00	[47]	3.85	21.86	3.04	26.95	4.3E−01	2.4E+00	3.4E−01	3.0E+00
Acetone	3.1E+04	[51]	8.88	36.19	7.41	27.15	2.9E−04	1.2E−03	2.4E−04	8.8E−04
Propionaldehyde	8.0E+00	[47]	0.10	1.67	0.10	1.98	1.3E−02	2.1E−01	1.2E−02	2.5E−01
2-Butanone (MEK)	5.0E+03	[47]	6.87	65.82	3.72	20.02	1.4E−03	1.3E−02	7.5E−04	4.0E−03

Particulate HAPs (ng/m³)										
Naphthalene (PAH)	3.0E+03	[47]	0.28	0.57	0.31	1.06	9.2E−05	1.9E−04	1.0E−04	3.5E−04
Biphenyl	4.0E+02	[52]	0.12	0.28	0.12	0.47	3.1E−04	7.0E−04	2.9E−04	1.2E−03
Benzo[a]pyrene	2.0E+00	[47]	0.31	1.43	0.34	1.57	1.5E−01	7.2E−01	1.7E−01	7.9E−01
Arsenic (As)	1.5E+01	[48]	46.74	654.43	4.42	37.75	3.1E+00	4.4E+01	2.9E−01	2.5E+00
Cadmium (Cd)	1.0E+01	[51]	9.36	60.14	1.51	11.12	9.4E−01	6.0E+00	1.5E−01	1.1E+00
Cobalt (Co)	1.0E+02	[51]	2.16	5.71	1.19	5.56	2.2E−02	5.7E−02	1.2E−02	5.6E−02
Chromium (Cr(VI))	1.0E+02	[47]	0.88	5.34	0.21	2.42	8.8E−03	5.3E−02	2.1E−03	2.4E−02
Manganese (Mn)	3.0E+02	[51]	169.55	663.88	51.24	181.73	5.7E−01	2.2E+00	1.7E−01	6.1E−01
Nickel (Ni)	9.0E+01	[51]	40.58	296.27	6.03	16.81	4.5E−01	3.3E+00	6.7E−02	1.9E−01
Lead (Pb)	1.5E+02	[47]	317.62	1772.66	41.27	336.77	2.1E+00	1.2E+01	2.8E−01	2.2E+00
Selenium (Se)	2.0E+04	[48]	57.90	327.73	4.79	89.71	2.9E−03	1.6E−02	2.4E−04	4.5E−03
∑HQ							1.0E+01		2.4E+00	

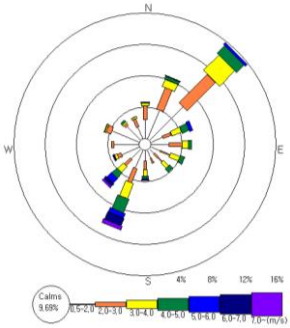
a) Noncarcinogenic benchmark concentrations were taken from RfC [47,52], MRL[51], REL [48].



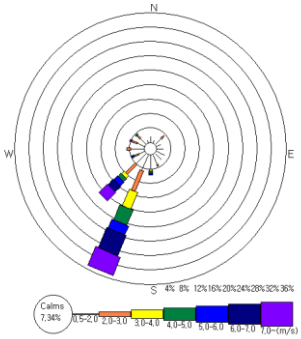
Spring season (2009-03-01 to 2009-05-31)



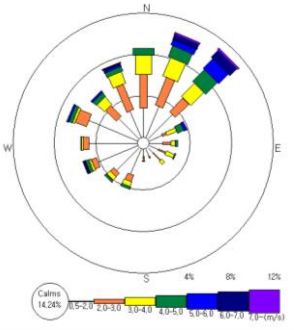
Spring campaign (2009-04-22 to 2009-04-29)



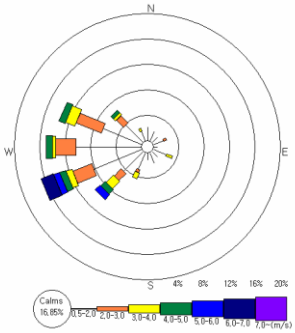
Summer season (2009-06-01 to 2009-08-31)



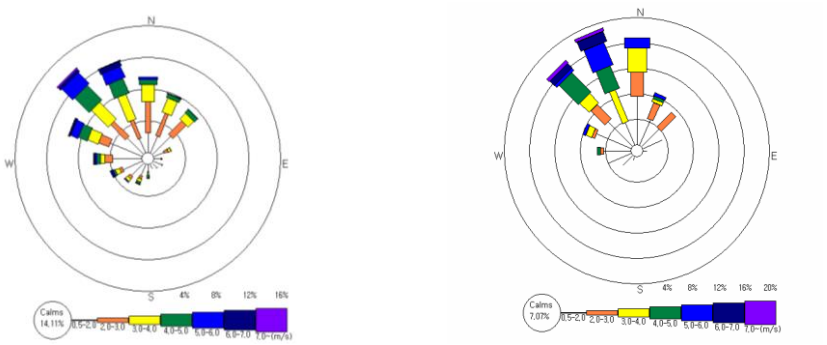
Summer campaign (2009-07-08 to 2009-07-15)



Autumn season (2009-09-01 to 2009-11-30)

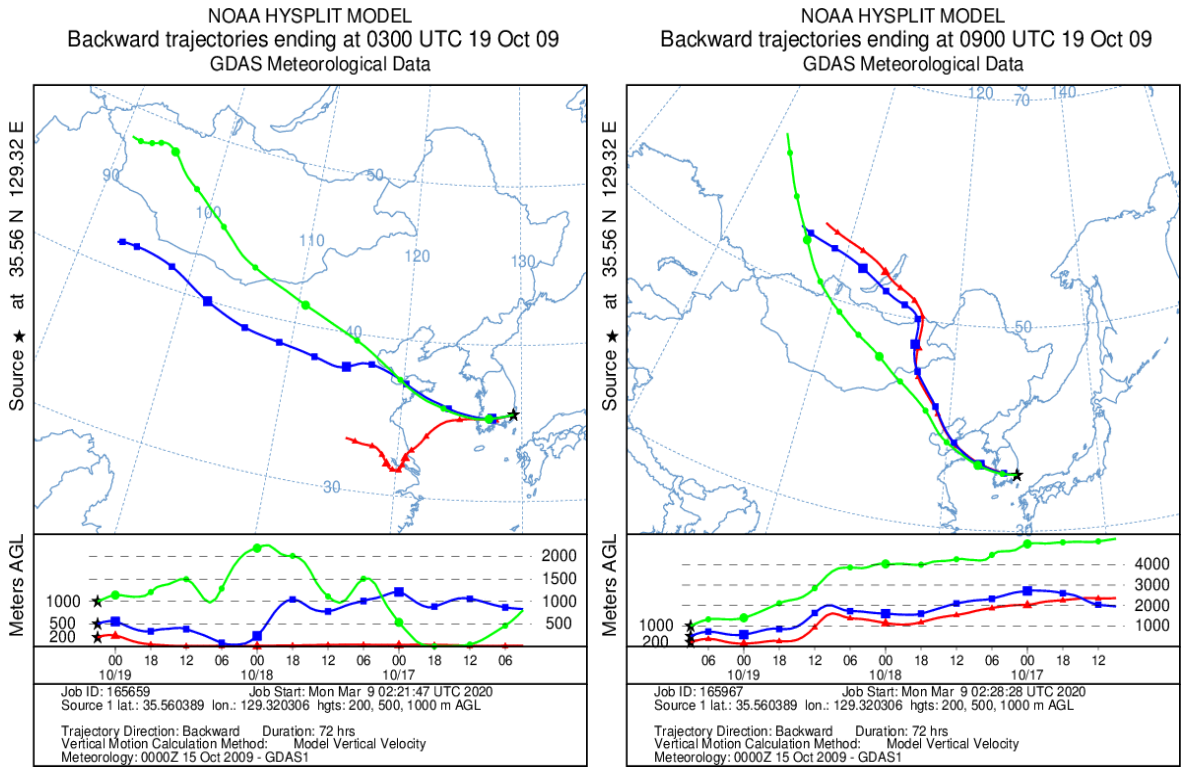


Autumn campaign (2009-10-15 to 2009-10-22)



Winter season (2009-12-01 to 2010-02-28) Winter campaign (2010-01-09 to 2010-01-16)

Figure S1. Windroses during seasonal monitoring campaigns in Ulsan.



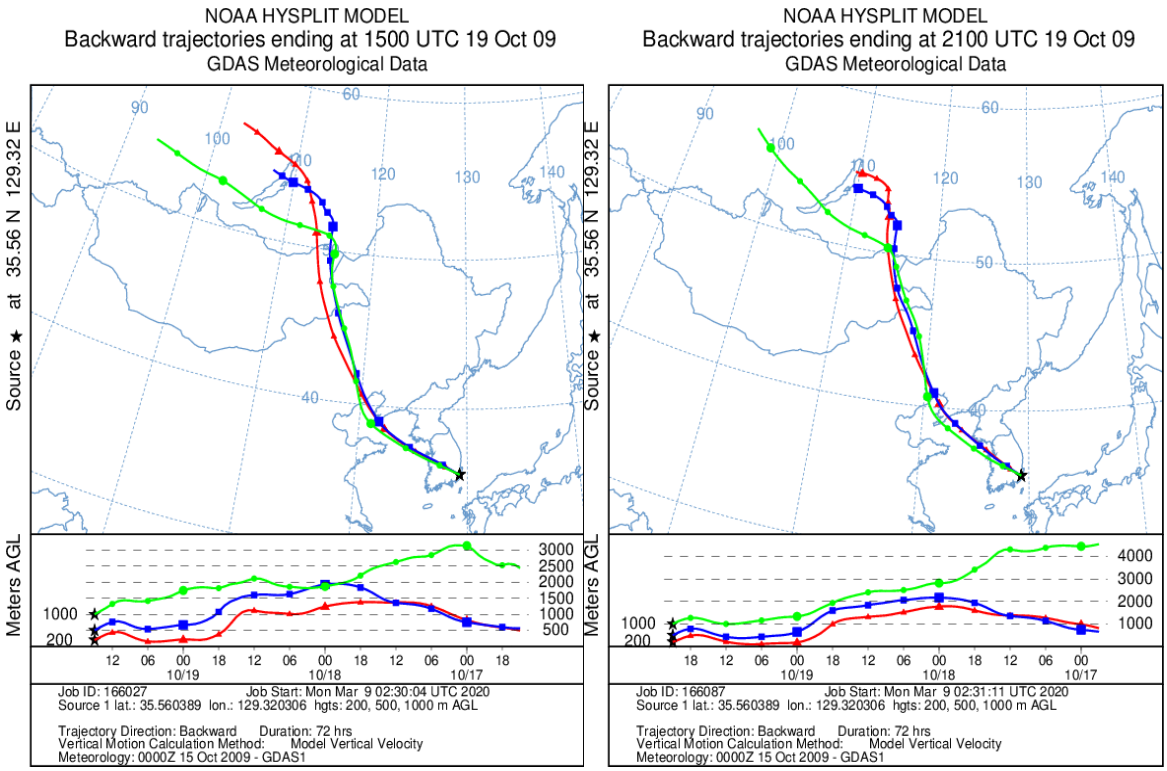


Figure S2. Examples of backward trajectories of air parcels by HYSPLIT modeling during the haze episode period (October 19, 2009) in Ulsan.

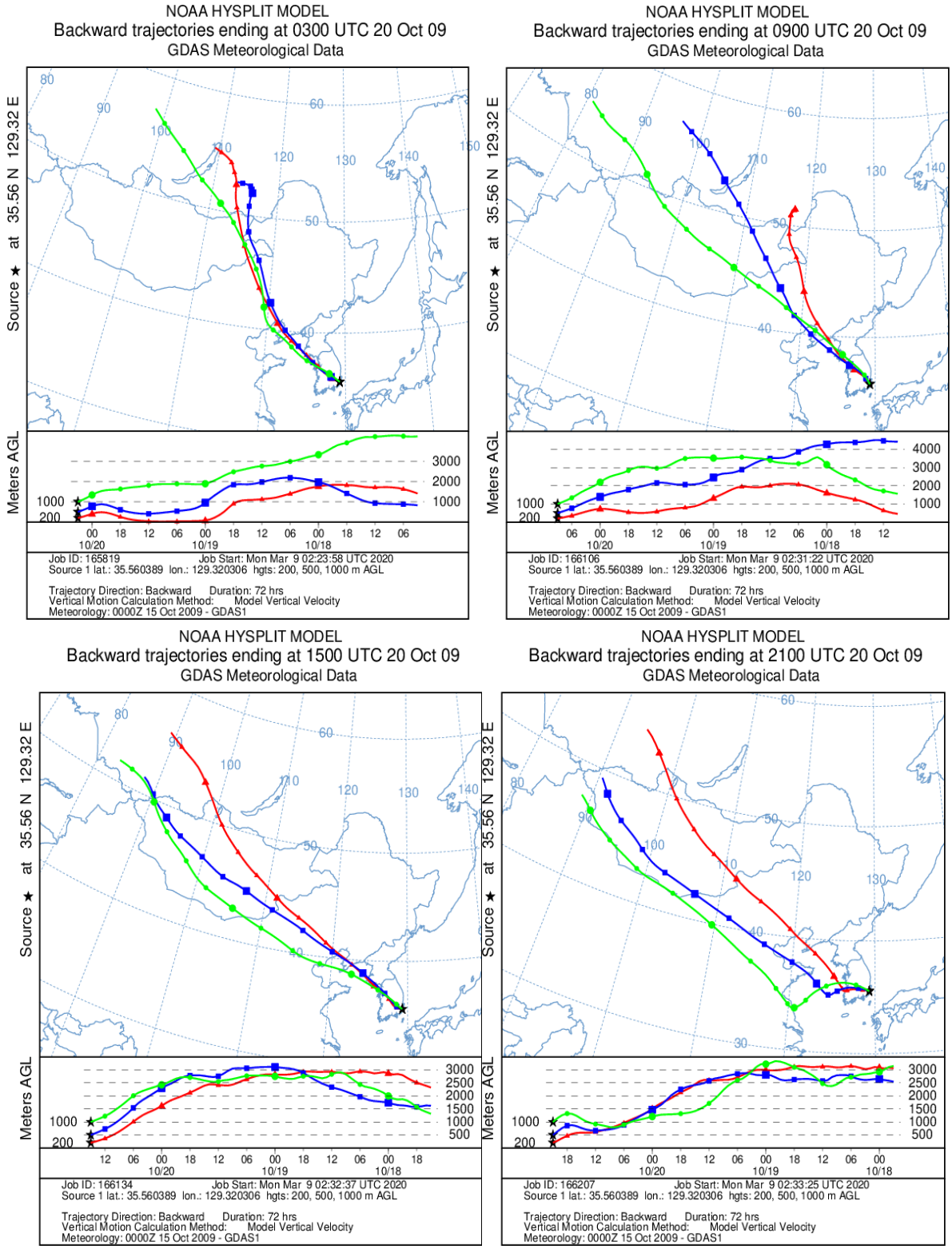


Figure S2b. Examples of backward trajectories of air parcels by HYSPLIT modeling during the haze episode period (October 20, 2009) in Ulsan.

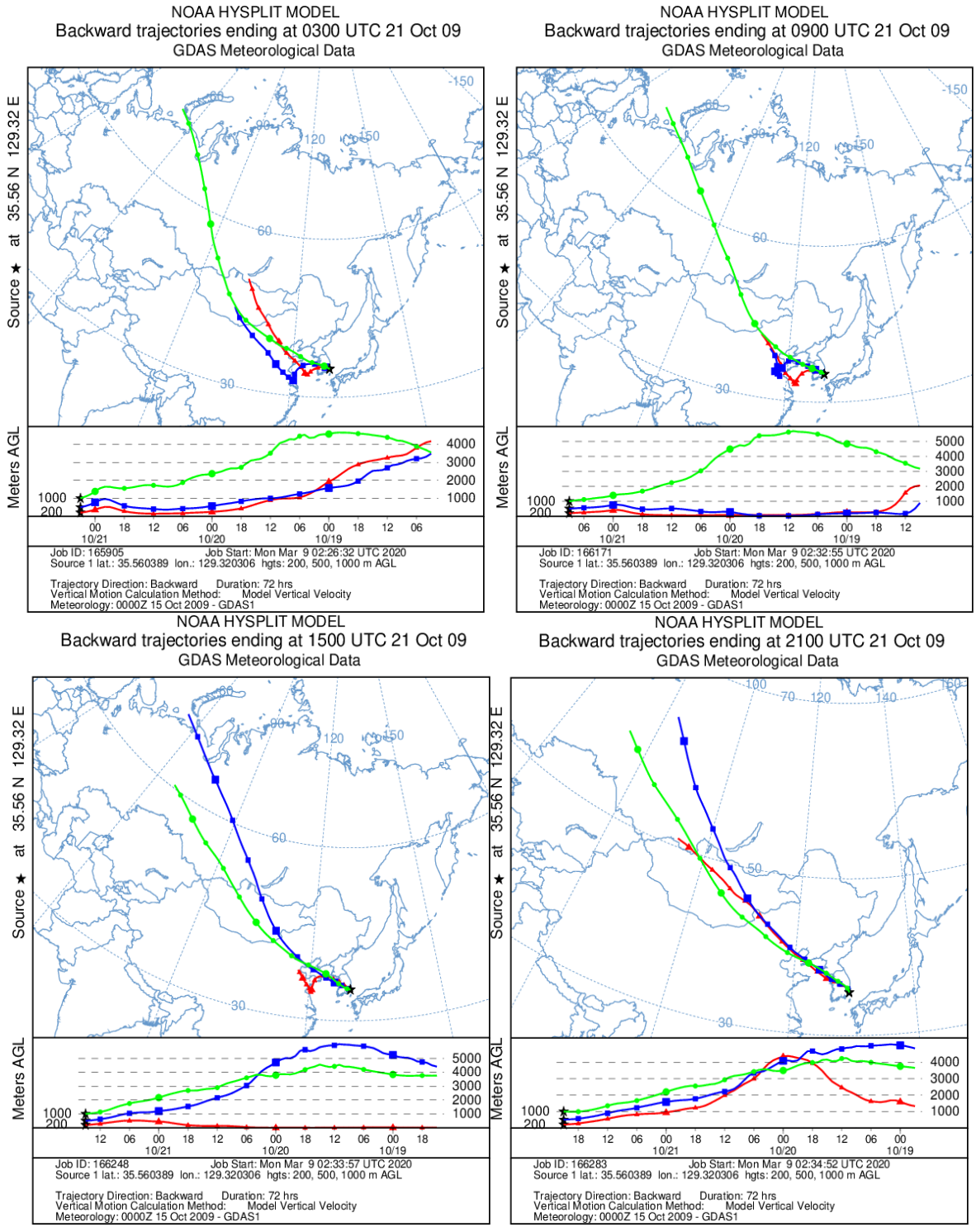


Figure S2c. Examples of backward trajectories of air parcels by HYSPLIT modeling during the haze episode period (October 21, 2009) in Ulsan.

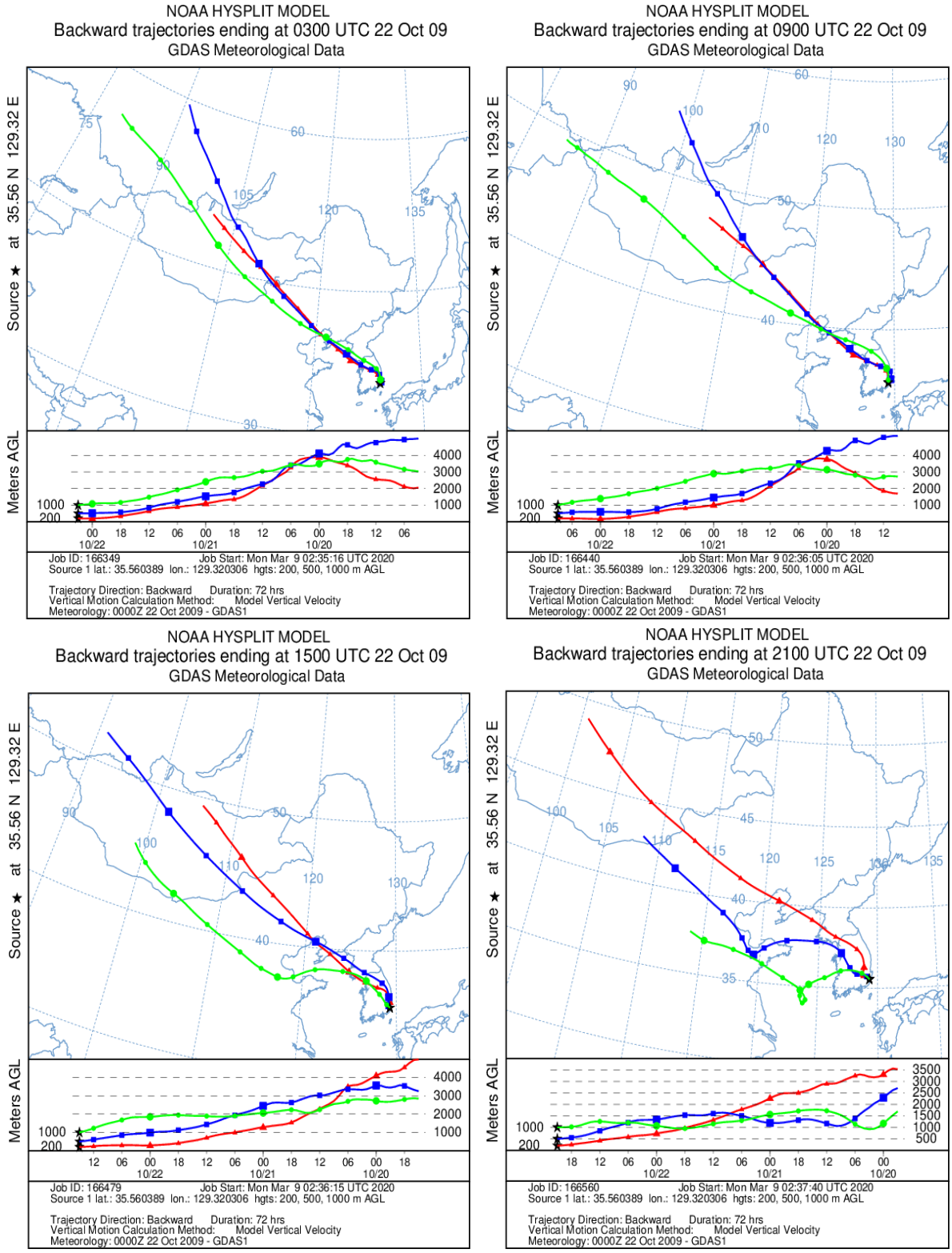


Figure S2d. Examples of backward trajectories of air parcels by HYSPLIT modeling during the haze episode period (October 22, 2009) in Ulsan.