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Summary of Korea Global Atmosphere Watch
2011 Report

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KMA Korea Meteorological Administration
GAW Global Atmosphere Watch

Summary of Korea Global Atmosphere Watch 2011 Report

Korea Meteorological Administration
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The Korea Meteorological Administration began global atmosphere watch at Sobaek Mt. meteorological Observatory, Danyang-gun, Chungcheongbuk-do, in 1987 to ensure a timely national-scale response to the pressing issue of climate change. That is the first site on the Peninsula for continuously monitoring background atmosphere.

Observation technology of climate change-inducing materials in the background atmosphere has been rapidly developed since the relocation of the site to the island of Anmyeon-do in Taean-gun, Chungcheongnam-do (36°32′N, 126°19′E; 45.7 m above mean sea level) in 1996. The site has been renamed the "Korea Global Atmosphere Watch Center (KGAWC)" in 2008. At present, 37 parameters, including greenhouse gases, aerosols, ultraviolet radiation, ozone, and precipitation chemistry, are being measured at the Center.

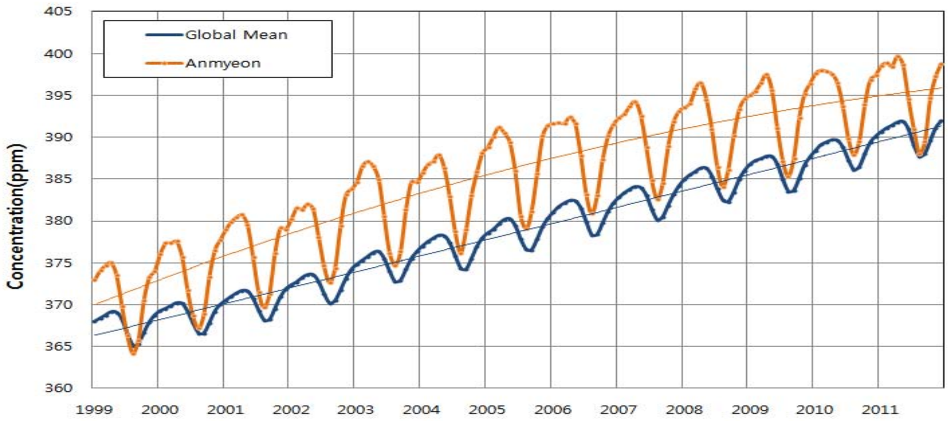
The KGAWC belongs to the WMO GAW regional station since 1998, and the Center has been actively engaged in international activities such as participating in international intercomparison experiments, organizing international workshops, and sharing data from WDCGG (World Data Centre for Greenhouse Gases). Due to its relatively pollution free environment, KGAWC provides an ideal site for observations that are geographically representative of the background atmosphere of Northeast Asia including the Korean Peninsula (Fig. 1).

Fig. 1. The Korea Global Atmosphere Watch Center is located at the relatively uncontaminated western coastal area.

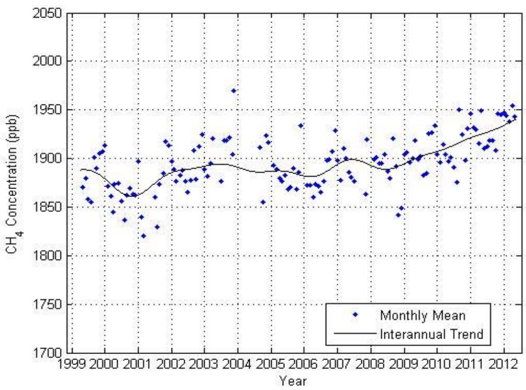
Greenhouse gases (GHGs)

Since 1999, the Center has been monitoring major greenhouse gases (GHGs) such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and chlorofluorocarbons (CFC-11) and CFC-12). In 2007, the number of GHGs monitored at the Center was increased to seven, with the addition of chlorofluorocarbon (CFC-113) and sulfur hexafluoride (SF_6). Figure 2 shows the concentration levels for the five GHG species observed at Anmyeon-do from 1999 to 2010, along with the NOAA/GMD global CO_2 concentration trends. The CO_2 concentrations at Anmyeon-do are substantially higher than the global average and the N_2O concentrations are steadily increasing, while CFC-11 and CFC-12 exhibit a continuously declining trend.

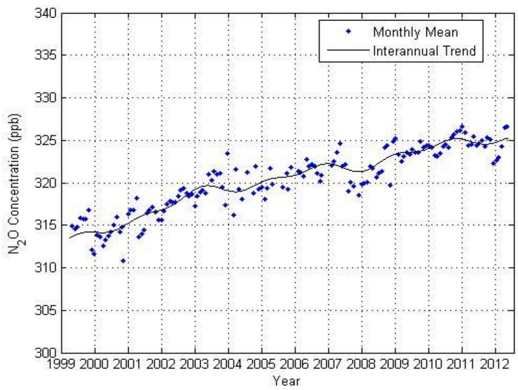
(a) CO_2



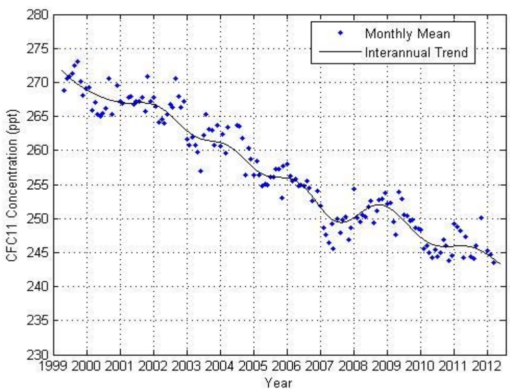
(b) CH_4



(c) N_2O



(d) CFC-11



(e) CFC-12

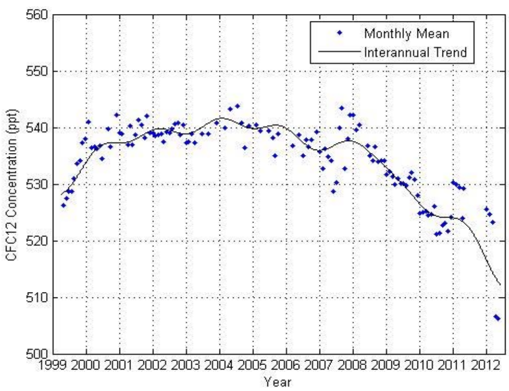


Fig. 2. Annual average of GHGs (CO_2, CH_4, N_2O, CFCs) concentrations for 1999-2011.

The average CO_2 concentration for the year 2011 recorded 395.7 ppm, an increase of 25.0 ppm (6.7 %) relative to the annual average of 370.7 ppm for 1999, and 5.2 ppm higher than the global average of 390.5 ppm for the same year as documented by NOAA/GMD (Table 1). The annual growth rate of CO_2 for the 13-year period from 1999 through 2011 was 2.16 ppm/year, higher than the global average of 1.9 ppm/year, but has slowed in recent years. Table 1 summarizes the annual growth rates of CO_2 concentrations for Anmyeon-do and the NOAA/GMD global averages.

Table 1. Anmyeon-do and global CO_2 concentrations (ppm) and annual mean CO_2 growth rates for 1999-2011.

Year		1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Anmyeon-do	Concentration (ppm)	370.7	373.8	376.9	379.7	382.6	384.3	387.2	388.7	389.9	391.4	392.5	394.5	395.7
	Growth rate (ppm/year)	+2.9	+3.4	+2.8	+3.2	+2.1	+2.4	+2.1	+1.5	+1.6	+1.2	+0.9	+2.0	+2.0
Global mean	Concentration (ppm)	367.6	368.8	370.4	372.4	375.0	376.8	378.8	380.9	382.7	384.8	386.3	388.5	390.5
	Growth rate (ppm/year)	+1.3	+1.3	+1.8	+2.4	+2.2	+1.6	+2.4	+1.8	+2.1	+1.8	+1.7	+2.4	+2.1

The methane (CH_4) concentration in 2011 was 1.929 ppm, an increase of 0.046 ppm (2.4 %) over 1999 (1.883 ppm), resulting in an annual mean growth rate of 0.0039 ppm/year (Table 2). The N_2O concentration for 2011 was 324.7 ppb, an increase of 10.7 ppb (3.4 %) over the value recorded in 1999 (314.0 ppb). The annual mean growth rate of N_2O is 0.9 ppb/year, and a persistently increasing trend is evident. All three species of CFCs (CFC-11, CFC-12, and CFC-113) are on the declining trend. There was a dramatic decrease of 25.0 ppt (-2.2 ppt/year) over 13 years in CFC-11, which fell from 270.4 ppt in 1999 to 245.4 ppt in 2011. CFC-12 also decreased by 12.6 ppt, from 532.5 ppt in 1999 to 519.9 ppt in 2011, which is a rather small annual mean decrease of -1.2 ppt/year (Table 2). Concentrations of CFC-113 recorded 76.8 ppt in 2010 and 77.3 ppt in 2011, an increase of 0.5 ppt over one year. The annual mean concentration of SF_6 for 2011 was 8.1 ppt, 0.3 ppt more than the 2010 average (7.8 ppt), suggesting a slight increase with every year.

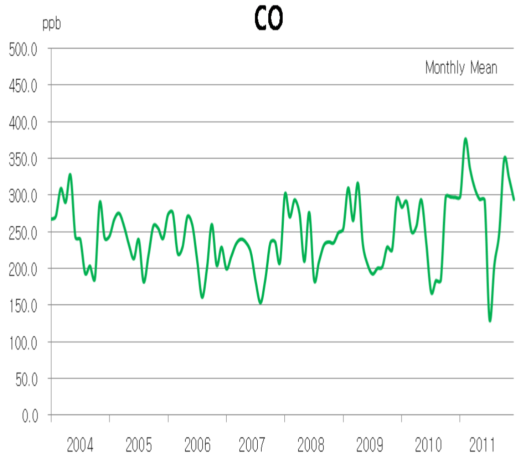
Table 2. Average concentrations for 2011 and annual mean growth rates for the 13-year period from 1999 through 2011 of major GHGs at the Anmyeon-do of the Korean Peninsula.

GHGs	CO_2	CH_4	N_2O	CFC-11	CFC-12
Average concentrations in 2011	395.7 (ppm)	1.929 (ppm)	324.7 (ppb)	245.4 (ppt)	519.9 (ppt)
13-year avg. growth rates	+2.16 (ppm/year)	+0.0039 (ppm/year)	+0.9 (ppb/year)	-2.2 (ppt/year)	-1.2 (ppt/year)

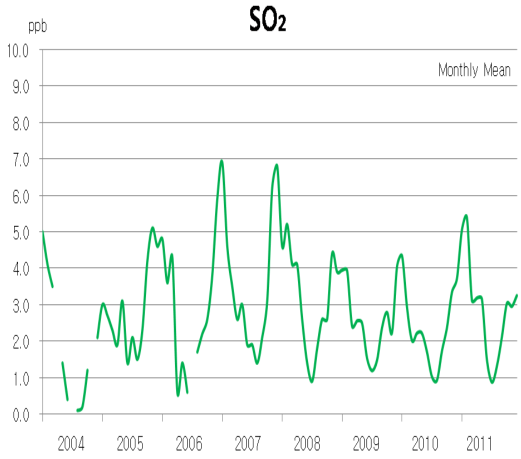
Reactive gases

The Center also monitors four species of reactive gases—CO, SO_2, NO_x, and O_3. Figure 3 shows monthly trends of concentrations for the four reactive gases.

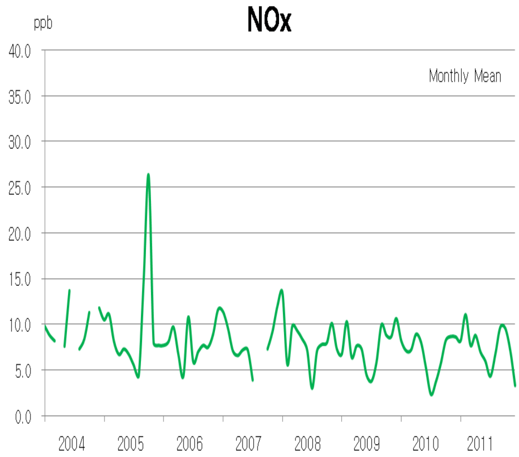
(a) CO



(b) SO_2



(c) NO_x



(d) O_3

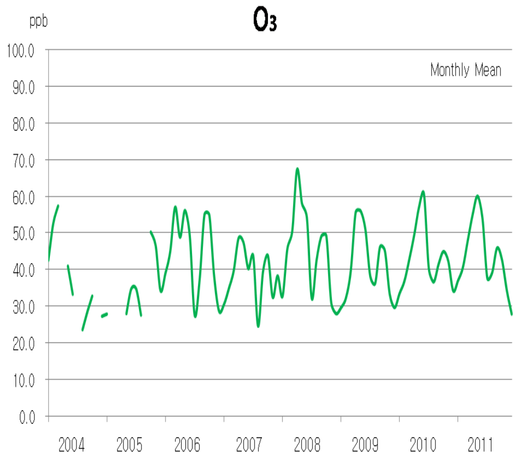


Fig. 3. Monthly variations in reactive gases (CO, SO_2, NO_X, O_3) concentrations (2004-2011)

Carbon monoxide (CO)—a by-product of fossil fuel or biomass burning—and OH radicals, affect methane concentrations. Average CO concentrations were 253.4 ppb in 2010 and 294.1 ppb in 2011, an increase of 40.7 ppb. The lowest values are most common in the summer, while values are higher in the winter and spring, and geographically, in the northern hemisphere, where many of the emission sources are located. Atmospheric ozone (O_3) near the Earth's surface absorbs energy in the infrared spectrum in the troposphere, and exhibits a relatively high concentration in mid- and high-latitude urban areas. O_3 concentrations tend to be higher in the spring and fall, and lower in the summer and winter. The annual average O_3 concentration for 2011 was 43.5 ppb, 0.2 ppb higher than the 2010 average (43.3 ppb). Concentrations of nitrogen oxides (NO_x), which are emitted from combustion engines, tend to be highest in the fall and lower in the summer. The annual mean concentration of NO_x in 2011 was 7.5 ppb, 0.7 ppb higher than the 2010 average (6.8 ppb). SO_2 concentrations averaged 2.9 ppb in 2011, 0.5 ppb higher than the previous year (2.4 ppb).

Atmospheric radiation

The Center continually monitors four atmospheric radiation parameters (direct solar radiation, global solar radiation, long-wave radiation, and net radiation) on clear days when cloudiness is less than 0.2 among 1.0. The monitored results are publicly available.

In 2011, the monthly maximum direct solar radiation was recorded in October (495.8 Wm^{-2}), and the minimum in August (307.9 Wm^{-2}). The annual average was 426.2 Wm^{-2}, 11.6 Wm^{-2} lower than the annual means (437.8 Wm^{-2}) for the last 12 years (1999-2010). With scattering of solar radiation, the monthly maximum for 2011 was recorded in June (141.1 Wm^{-2}), the minimum in December (54.4 Wm^{-2}). The annual average was 82.6 Wm^{-2}, 44.8 Wm^{-2} lower than the means of the last 12 years (127.4 Wm^{-2}).

Overall, downward and upward solar radiations yield the highest values in the summer, although they may be comparatively lower during the rainy season or in the event of localized downpours. These downward and upward solar radiations were highest in May of 2011, recording 565.9 Wm^{-2} and 93.5 Wm^{-2} respectively, and lowest in December, recording 250.4 Wm^{-2} and 56.2 Wm^{-2} respectively. Downward solar radiation averaged 408.4 Wm^{-2}, and upward solar radiation 77.9 Wm^{-2} in 2011, 16.3 Wm^{-2} and 7.5 Wm^{-2} higher than the mean value of the last 12 years (1999-2010) (Fig. 4).

In 2011, terrestrial radiation peaked in July, with downward radiation recording 392.7 Wm^{-2} and upward radiation, 478.0 Wm^{-2}. Downward terrestrial radiation was lowest in January (212.8 Wm^{-2}), while upward radiation was lowest in December (296.2 Wm^{-2}). The downward and upward terrestrial radiation averages for 2011 were 296.4 Wm^{-2} and 387.1 Wm^{-2}, and 13.8 Wm^{-2} and 10.7 Wm^{-2} lower than the mean value of the last 12 years (Fig. 5).

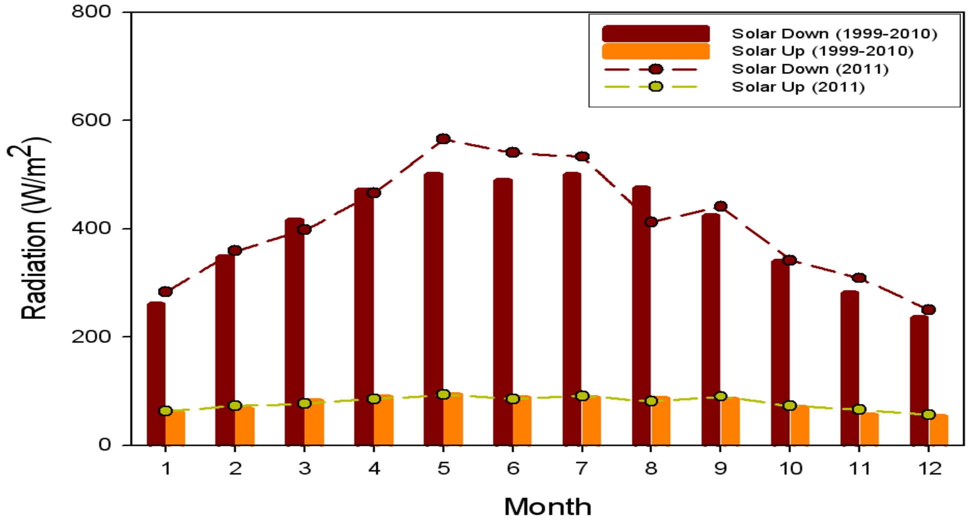


Fig. 4. Monthly averages of solar radiation in the clear day at the Anmyeon-do

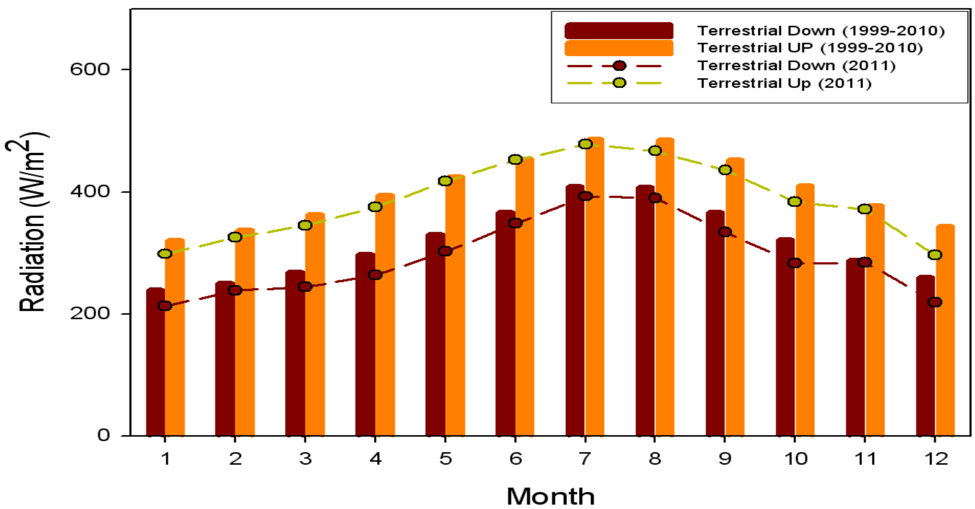


Fig. 5. Monthly averages of terrestrial radiation in the clear day at the Anmyeon-do

Aerosol

Optical, physical and chemical characteristics of aerosol are measured at the Center. Among optical characteristics, scattering coefficients, absorption coefficients, Angstrom exponent, and single scattering albedos are monitored using a nephelometer (Model TSI 3563) and an athelometer (Model AE16). Among the nephelometer- measured scattering coefficients, the coefficients measured at 550 nm averaged 83.25 Mm^{-1} in 2011, with the highest and the lowest values recorded in February (159.7 Mm^{-1}) and July (52.40 Mm^{-1}) respectively.

The average of athelometer-measured absorption coefficients was 7.86 Mm^{-1}, with the highest and the lowest values recorded in October (11.92 Mm^{-1}) and January (5.07 Mm^{-1}) respectively.

The annual average of the Angstrom exponent, computed using the total scattering coefficients from the nephelometer was 1.61, with the highest and the lowest values recorded in July (1.83) and January (1.30) respectively. Single scattering albedos, calculated using the aerosol scattering and absorption coefficients, averaged 0.86 (for 2011), with the highest and lowest values recorded in February and March (0.93) and September (0.52) respectively.

For monitoring physical properties of aerosols, the Center relies on the Aerodynamic Particle Sizer (APS) and the Scanning Mobility Particle Sizer (SMPS) to capture the size distribution of aerosols between 0.01 and 20 ㎛. The daily average volume concentration of particles 0.5-20.0 ㎛ in diameter measured using the APS for 2011 was 30.5 $㎛^3$ $㎝^{-3}$. The highest value of 58.1 $㎛^3$ $㎝^{-3}$ was recorded in February.

Aerosol mass concentrations provide information on Asian Dust, a sand and duststorm phenomenon common in Northeast Asia, and are used as an air quality standards at many governmental agencies. To determine aerosol mass concentrations, the Center employs beta-ray attenuation (PM_{10}) and optical instruments (PM_{10}, $PM_{2.5}$, and $PM_{1.0}$). The 2011 average mass concentration for PM_{10}, based on beta-ray attenuation, was 39.2 ㎍ m^{-3}, lower than the 12-year (1999-2010) average of 54.9 ㎍ m^{-3}. Figure 6 shows the occurrence of extreme aerosol concentration (1200, 800, and 400 ㎍ m^{-3}) in Anmyeon-do for 1999~2011. The yellow sand phenomena for 2000~2002 were very severe. The most severe yellow sand over 1200 ㎍ m^{-3} occurred for 5days in 2002, and 2 days in 2006 and 2010.

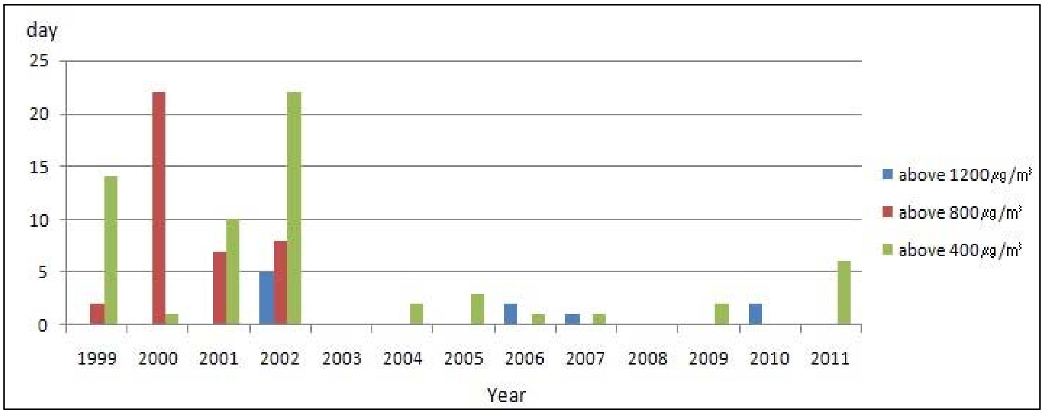


Fig. 6. Occurrence day with a maximum aerosol concentration recorded over 1,200, 800, and 400 ㎍ m-3 for 1999-2011 at the Anmyeon-do.

Ozone and ultraviolet radiation

In general, the annual mean concentration of ozone indicates a gradual decline from 1979 to the early 1990's, which then turned into a gradual increase after 1993. On the Korean peninsula, where the distribution of total ozone is monitored at Anmyeon-do, Pohang, and Seoul, there is a pronounced northward increasing trend.

The daily maximum value of total ozone measured using a Dobson spectrophotometer in Seoul for 2011 was 448 DU (1 April) and the daily minimum, 244 DU (13 November). The average annual variation of total ozone for 1985-2011 recorded the highest value in March (362 DU), and the lowest in October (291 DU), an annual range of 71 DU. Interannual change in total ozone average was the highest in 2010 (343 DU) and the lowest in 1988 (313 DU).

As for the total ozone amount measured in Pohang using a Brewer spectrophotometer (1994-2011), the average for the entire period (1994-2011) was 313.7 DU. Interannual change increased after 1994, peaking at 336.3 DU in 2001, after which it shows a sharp drop, recording the lowest value (302.7 DU) in 2003, and subsequently alternating between rises and falls. The intra-annual change of monthly total ozone averages was the highest in April with 348.0 DU, and the lowest in October with 283.9 DU. Seasonal changes were pronounced, with the peaks concentrated in the spring and the lowest values, in the fall.

At Anmyeon-do, vertical profiles of stratospheric ozone concentrations have been documented using an ozone lidar (model: StraZon 3079) since 2002. The annual average is highest in March and April at 21-23 km above ground, and relatively low in September at 25 km above ground.

UV-Biometers (Solar Light Co. Model #501) are in place at 5 sites—Pohang, Mokpo, Anmyeon-do, Gosan (Jeju Island), and Gangneung—as part of a multi-year programme initiated in 1994. This network serves to monitor harmful surface ultraviolet radiation over the Korean Peninsula. Annual trends of monthly average total UV radiation at Anmyeon-do is characterized by seasonal variations, with the highest value recorded in August and the lowest in December. Figure 7 compares the monthly average UV radiation index for Anmyeon-do from 1999 to 2011 and the UV index for 2011. This index records its highest annual value in August. Overall, the UV index for 2011 was lower than the average value of 2001-2010. Table 3 illustrates dermatological response patterns at each UV index level.

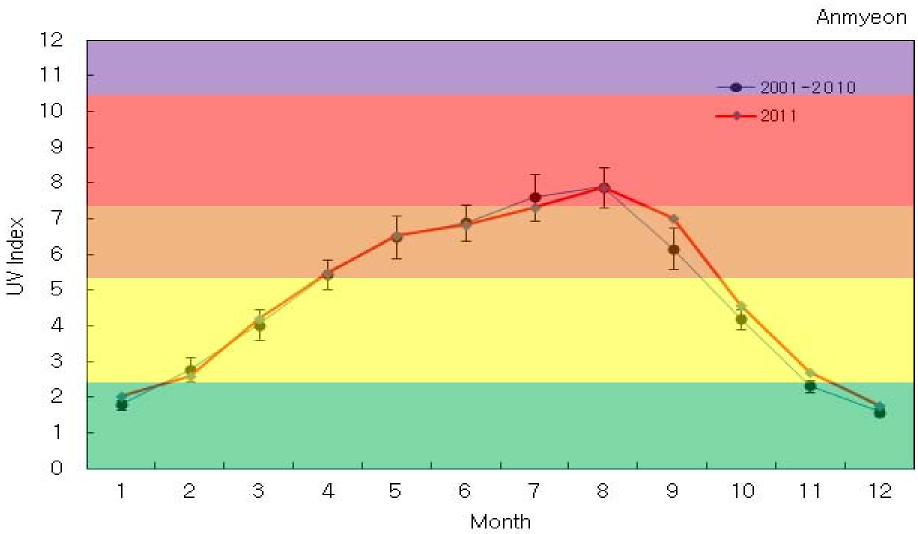


Fig. 7. Monthly averages of UV indices at the Anmyeon-do GAW Center for 2001-2010 and for 2011.

Table 3. Dermatological response according to UV index

UV Index	Description		Media Graphic color
0-2	Low	No danger to the average person	Green
3-5	Moderate	Little risk of harm from unprotected sun exposure	Yellow
6-7	High	High risk of harm from unprotected sun exposure	Orange
8-10	Very High	Very high risk of harm from unprotected sun exposure	Red
≥11	Extreme	Extreme risk of harm from unprotected sun exposure	Violet

Precipitation chemistry

At the Anmyeon-do GAW Center, precipitation acidity is calculated based on precipitation-weighted means. The pH value at Anmyeon-do for 2011 was 4.64, and this value is lower (more acidic) than the 12-year (1997-2010) average of 4.69. The precipitation pH (acidity) for Anmyeon-do most frequently lies within the range of 4.5-5.0. However, the frequence of pH 4.5-5.0 decreased, instead, pH between 3.5-4.0 and pH between 6.0-6.5 increased in 2011 compared to that of the 1997-2010 mean (Fig. 8).

In Amyeon-do, proportion of Na^{+} and Cl^{-}, components of sea salt, is larger than other ions because Anmyeon-do station is closely-located in the coast of the West Sea. High concentrations of acids such as NO_3^{-} and SO_4^{2-} occur in the wet deposition especially during the rainy summer season.

NH_4, a common neutralizing agent, yielded large amounts in the wet deposition during the summer, while higher concentration of Ca^{2+} occurs in a dry deposition compared with other substances.

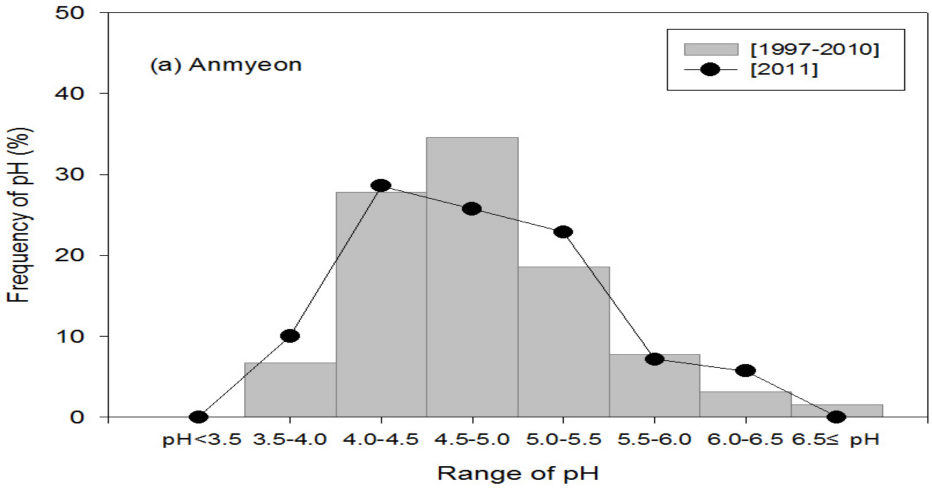


Fig. 8. Comparison of precipitation pH range frequencies as measured at the Anmyeon-do GAW Center for 1997-2010 and 2011.

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