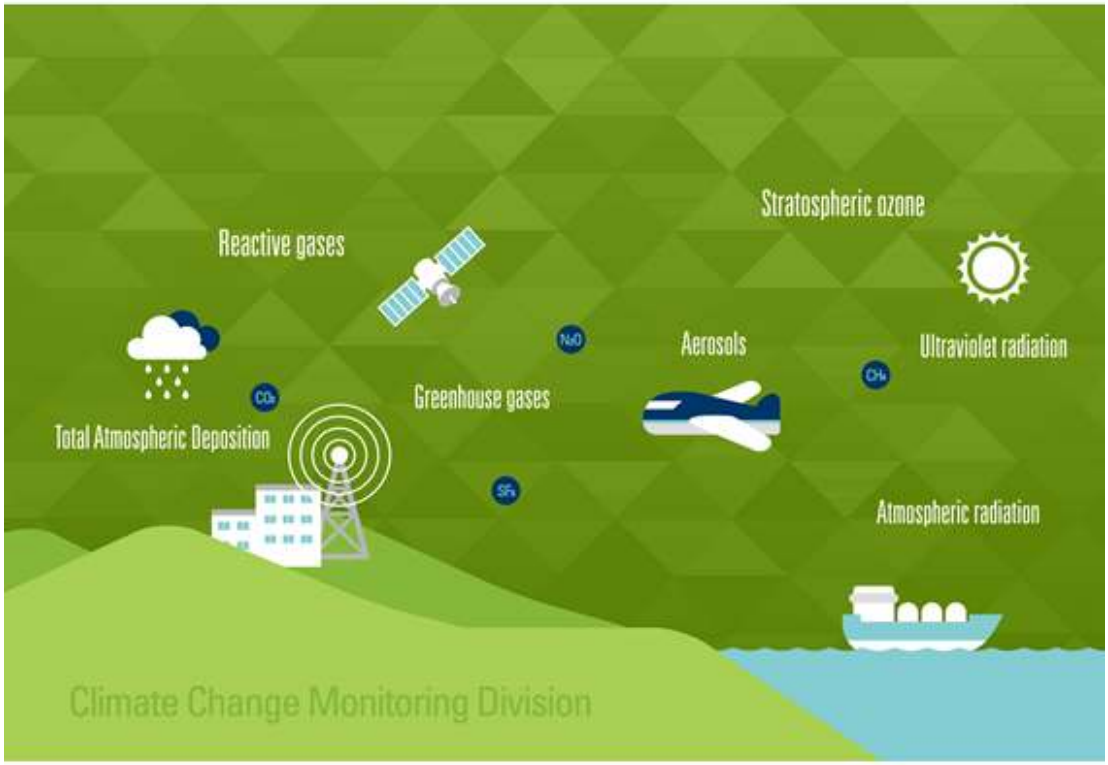
Summary of Korea Global Atmosphere Watch
2016 Report



KMA GAW

Summary

☐ Greenhouse gases

The Korea Meteorological Administration (KMA) has been monitoring seven greenhouse gases including carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), three chlorofluorocarbons (CFC-11,12,113), and sulfur hexafluoride (SF_6) at Amyeondo since 1999, Jeju Gosan since 2012, Ullengdo, and Dokdo stations since 2013, respectively.

In 2016 the annual mean concentrations of CO_2 were measured as follows, and the concentrations are steadily on the rise: 409.9 ppm at Anmyeondo, 409.5 ppm at Gosan, 407.5 ppm at Ulleungdo, and 407 ppm at Dokdo. The CO_2 concentration at Anmyeondo station, which has the longest record of CO_2 in Korea, has shown that its absolute difference from the annual mean concentration in 2015 was up by 2.9 ppm, which is higher than the 10-year average increase of 2.3 ppm/yr over the last decade (2007 to 2016). According to the National Oceanic and Atmospheric Administration (NOAA), the global mean average of CO_2 in 2016 was 402.9 ppm, which is 7 ppm lower than the values at Anmyeondo station.

The concentrations of other greenhouse gases—CH_4, N_2O and SF_6—are also on the increase: their annual mean concentrations were increased by 13 ppb, 1 ppb, and 0.2 ppt, respectively, compared to the 2015 mean average. On the other hand, CFCs are gradually decreasing due to the Montreal Protocol, marking the lowest annual average concentrations since observations began in 1999.

☐ Reactive gases

Reactive gases, such as ozone (O_3), carbon monoxide (CO), nitrogen compound (NO_X), and sulfur dioxide (SO_2), belong to main observation parameters in the GAW due to their effect on air quality, and because they also act as precursors to the generation of greenhouse gases and aerosols. Their relatively short life time in the atmosphere results in wide regional differences.

In Gosan in 2016, the annual mean concentration of reactive gases were as follows: 39.3 ppb of O_3, 216.4 ppb of CO, 3.6 ppb of NO_X, and 0.5 ppb of SO_2 . In terms of seasonal distributions, O_3 was high in spring and autumn while low in summer and winter. CO, NO_X and SO_2 were low in summer and high in winter. In spring over 50 ppb of O_3 was evenly distributed regardless of wind direction and wind speed. The level of CO was relatively increased when a northwest wind blows from the Yellow sea. The level of NO_X was higher in the east-west direction except in summer; the stronger the wind, the higher the concentration. The level of SO_2 was low, especially in summer and autumn regardless of wind direction and wind speed, and it was slightly increased in spring and winter in a westerly wind.

Over the last five years (2012-2016) the concentration of O_3 measured in Gosan has slightly increased until 2015 and then started to decrease in 2016. During the five-year period, CO, NO_X and SO_2 were observed at similar levels without noticeable increase or decrease.

☐ Aerosols

The annual average PM10 mass concentration was 35 $\mu g/m^3$ at Anmyeondo in 2016, which was 12% lower compared to the past 10-year average (2006-2015), and this has been substantially decreasing since 2005. The annual average PM10 mass concentration at Gosan, Jeju in 2016 was 31 $\mu g/m^3$, which was 7%

higher than the previous five-year average (2011-2015).

In 2016, the aerosol volume concentrations at Gosan were lower than those in the past seven years (2009-2015). And the total aerosol number concentration measured by condensation particle counter at Gosan was lower than that of the last two years (2014-2015) except for May and June.

The light-scattering coefficient and light absorption coefficient at Anmyeodo were 69.0 Mm^{-1} and 8.8 Mm^{-1}, respectively. The light scattering coefficient was the lowest in 10 years while the light absorption coefficient was similar to that in 2015.

The PM10 and PM2.5 particles (Low Volume Sampler) have been collected once a week at Anmyeondo site, and their mass concentration and ionic species have been analyzed. The annual average of mass concentrations of PM10 and PM2.5 particles were 41.0±30.4 (n=46) and 34.8±22.1 (n=49) $\mu g/m^3$ in 2016, respectively, which were lower than the average of the previous eight years (2008-2015). And the concentrations of secondary inorganic components (nss-SO_4^{2-}, NO_3^-, and NH_4^+) of PM10 were also lower than the average of the past eight years.

The aerosol optical depth (AOD) and angstrom exponent (AE) were measured with the PFR at Gosan (Jeju) and Anmyeondo in 2015 and 2016. The results have shown that the AOD was high in spring and low in winter. On the other hand, the AE was low in spring and high in autumn and winter.

The vertical distribution of dust aerosol on November 27-28, 2016 at Anmyeondo was measured by a lidar. In this case, the total attenuated backscatter and depolarization ratio showed high values from surface to the 2.5 km height, indicating an increase in the non-spherical dust aerosol.

☐ Atmospheric radiation

The annual averages of solar downward, direct, and diffuse radiation at Gosan (Jeju) in 2016 were 149.4 W/m^2, 104.3 W/m^2, and 79.3 W/m^2, respectively. However, the analysis of those at Anmyeondo site was made due to the calibration of instruments during the winter season.

The monthly average of solar radiation increases in spring and decreases in winter due to seasonal variations. In summer season, however, in spite of the high solar zenith angle, cloud and precipitation reduce the solar radiation. In 2016 at Anmyeondo, the maximum monthly averages of solar radiation were 46.8 W/m^2 (upward) in May and 255.0 W/m^2 (downward) in May, and the minimum monthly averages were 20.0 W/m^2 (upward) in December and 87.7 W/m^2 (downward) in January.

As infrared radiation (IR) is influenced by air and surface temperature, vertical distribution of humidity, cloudiness, and hydrometeor, the IR radiation is generally low in winter and high in summer. At Anmyeondo in 2016, the maximum monthly averages of IR radiation were 462.0 W/m^2 (upward) in August and 386.5 W/m^2 (downward) in July; the minimum monthly averages of IR radiation were 313.2 W/m^2 (upward) in January and 248.3 W/m^2 (downward) in February.

☐ Stratospheric ozone and Ultraviolet radiation

The total ozone column (TOC) of 2016 at Anmyeondo, Gosan (Jeju), and Seoul were 321 DU, 291 DU, and 324 DU, respectively. They dropped by 3% (Anmyendo), 8% (Gosan), and 4% (Seoul) from the annual average values of 2015. The highest TOC in 2016 was 433 DU (Anmyeondo) on March 27, 419 DU (Gosan) on March 27, and 438 DU (Seoul) on February 5. The TOC showed a significant seasonal variability from February to May and recorded

the lowest in October. The monthly average values of TOC decreased in spring compared to the mean values of the past a few years at three respective sites.

As for UVA, the maximum cumulative daily radiation in 2016 was 1.55 MJ/m^2 in Gangneung (June 1); 1.52 MJ/m^2 in Seoul (July 9); 1.45 MJ/m^2 in Ullenugdoon (June 1); 1.38 MJ/m^2 in Anmyeondo (June 25); 1.45 MJ/m^2 in Pohang (June 2); 1.52 MJ/m^2 in Mokpo (July 23); 1.55 MJ/m^2 in Gosan (May 23). The highest values were mainly observed in May, June, and July.

For UVB, the maximum cumulative daily radiation in 2016 was 5.0 KJ/m^2 in Gangneung (July 22); 4.15 KJ/m^2 in Seoul (May 7); 5.88 KJ/m^2 in Ullenugdo (July 15); 5.44 KJ/m^2 in Anmyeondo (July 14); 4.79 KJ/m^2 in Pohang (July 15); 5.41 KJ/m^2 in Mokpo (May 31); 5.87 KJ/m^2 in Gosan (May 23). Ultraviolet radiation is influenced by solar zenith angle and daylight hours. Therefore, the cumulative daily radiation dose values were high from May to June, while the cumulative radiation dose values relatively low from July to August affected by the rainy season.

□ Total Atmospheric Deposition

The average annual precipitation at Anmyeondo, Gosan, Ulleungdo, and Uljin was 658.0 mm, 1543.5 mm, 2079.2 mm, and 1196.3 mm, respectively. The precipitation at all sites, except Anmyeondo, in 2016 was greater than the 10-year (2006-2015) average precipitation.

The average annual acidity (pH) in 2016 was 4.94, which was higher than that of the past 10 years (2006-2015)—which was 4.69. The average annual acidity at Anmyeondo, Gosan, Ulleungdo, and Uljin was 4.90, 5.08, 4.81, and 5.12, respectively, showing Ulleungdo had the lowest and Uljin had the highest.

The acidic rain frequency rate (pH<5.6) in 2016 was 82.5% at Anmyeondo, 78.7% at Gosan, 90.5% at Ulleungdo, and 66.2% at Uljin. The frequency rate with pH lower than 4.5 was the highest at Anmyeondo with 19.3%, followed by 16.8% at Ulleungdo, 10.6% at Gosan, and 0.0% Uljin. When compared to the average over the previous 10 years, the frequency in 2016 was lower at all sites except Ulleungdo.

The total deposition in 2016 was 7,898 mg/m^2, showing a slightly decreasing trend since 2010. The sum of dry deposition has been lower than the sum of wet deposition since 2003. The monthly total deposition in 2016 was the highest in August, and the dry and wet deposition was the highest in May and July, respectively. The previous 10-year average (2006-2015) for the total and dry depositions and for the wet deposition was the highest in December and August, respectively.