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The state of greenhouse gases in the atmosphere using global observations through 2016

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We present results from the thirteen annual Greenhouse Gas Bulletin (http://www.wmo.int/pages/prog/arep/gaw/ghg/GHGbulletin.html) of the World Meteorological Organization (WMO). The results are based on research and observations performed by laboratories contributing to the WMO Global Atmosphere Watch (GAW) Programme (www.wmo.int/gaw).

The Bulletin presents results of global analyses of observational data collected according to GAW recommended practices and submitted to the World Data Center for Greenhouse Gases (WDCGG). Bulletins are prepared by the WMO/GAW Scientific Advisory Group for Greenhouse Gases (http://www.wmo.int/pages/prog/arep/gaw/ScientificAdvisoryGroups.html) in collaboration with WDCGG.

Observations used for global analysis are collected at more than 100 marine and terrestrial sites worldwide for CO_2 and CH_4 and at a smaller number of sites for other greenhouse gases. The globally averaged surface mole fractions calculated from this in situ network reached new highs in 2016, with CO_2 at 403.3 $\pm$ 0.1 ppm, CH_4 at 1 853 $\pm$ 2 ppb and N_2O at 328.9 $\pm$ 0.1 ppb. These values constitute, respectively, 145%, 257% and 122% of pre-industrial (before 1750) levels. The record increase of 3.3 ppm in CO_2 from 2015 to 2016 was larger than the previous record increase observed from 2014 to 2015, and the average growth rate over the last decade. The El Niño event in 2015/2016 contributed to the increased growth rate through complex two-way interactions between climate change and the carbon cycle. The increase of CH_4 from 2015 to 2016 was slightly smaller than that observed from 2014 to 2015, but larger than the average over the last decade. The increase of N_2O from 2015 to 2016 was also slightly smaller than that observed from 2014 to 2015 and the average growth rate over the past 10 years. The National Oceanic and Atmospheric Administration (NOAA) Annual Greenhouse Gas Index (AGGI) shows that from 1990 to 2016, radiative forcing by long-lived greenhouse gases (LLGHGs) increased by 40%, with CO_2 accounting for about 80% of this increase.

The bulletin puts current changes in the levels of CO_2 into the context of the past observed changes. Over the last ~800 000 years, pre-industrial atmospheric CO_2 content remained below 280 ppm across glacial and interglacial cycles, but it has now risen to the 2016 global average of 403.3 ppm. The most-recent high-resolution reconstructions from ice cores demonstrate that changes in CO_2 have never been as fast as in the past 150 years. Geological records show that the current levels of CO_2 correspond to an "equilibrium" climate last observed in the mid-Pliocene (3–5 million years ago), a climate that was 2–3 $^{\circ}$C warmer, where the Greenland and West Antarctic ice sheets melted and even some of the East Antarctic ice was lost, leading to sea levels that were 10–20 m higher than those today.

Further details can be found in the WMO Greenhouse Gas Bulletin which is available online on all six official languages of WMO at https://library.wmo.int/opac/index.php?lvl=notice_display&id=20041#.WlC6oFWnHIU