Global temperatures rise one degree per 40 DU decrease in ozone

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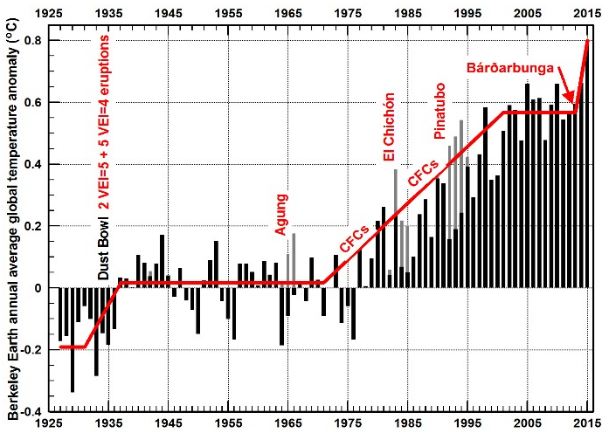

Fig. 1. Berkeley Earth annual average temperature anomalies (black bars), corrections for cooling by aerosols following explosive eruptions (gray bars), and trend lines (red) for comparison with Fig. 3. Largest volcanic eruptions labeled in red. The major Dust Bowl droughts peaked in 1934, 1936, and 1939-1940 after a highly unusual sequence of 2 VEI=5 and 6 VEI=4 eruptions around the Pacific Ocean in 1931 through 1937.

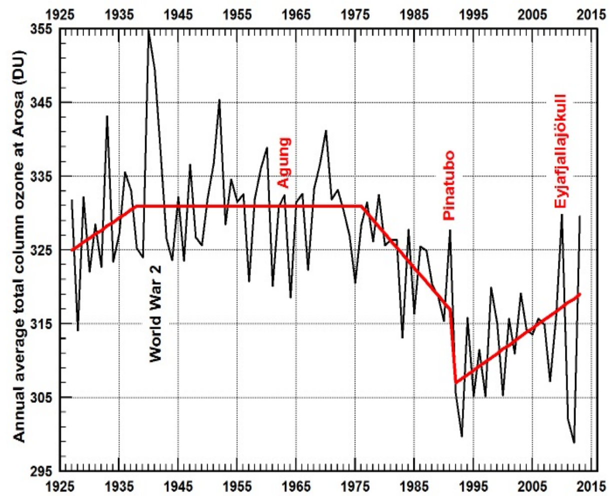

Fig. 2. Annual average total column ozone measured at Arosa, Switzerland since 1927. Red trend lines are for comparison with Fig. 3. The largest volcanic eruptions are labeled in red.

Annual average global temperatures (Fig. 1) remained relatively constant from 1927 to 1931, rose from 1931 to 1937, the Dust Bowl drought years, remained relatively constant from 1938 to 1971, rose sharply from 1971 to 2001, remained relatively constant from 2001 through 2013, the global warming hiatus, and rose suddenly during and since the 6-month eruption of Bárðarbunga beginning in August 2014, the highest rate of basaltic lava extrusion since 1783, the cause of the current heat wave.

Annual average total column ozone measured at Arosa, Switzerland since 1927 (Fig. 2) rose from 1927 to 1937, remained relatively constant from 1937 to 1976, decreased from 1976 to 1991 most likely because of emissions of CFC gases, suddenly decreased following the eruption of Mt. Pinatubo in 1991, the largest volcanic eruption since 1912, and then slowly recovered over the next decade. A similar amount of depletion followed the eruption of Eyjafjallajökull volcano in 2010, a much smaller volcano but more effusive.

Fig. 3 shows the temperature data plotted as a function of the ozone data where the numbers are the year of each data point and the red line represents the trends shown in Figs. 1 and 2. Note the general trend of the data with temperatures increasing at a rate of 1.0°C per 40 DU decrease in ozone. The scatter in data is dominated by the effects of 7 eruptions with VEI=5 and more than 50 eruptions with VEI=4 during this period that caused changes similar to, but much smaller than, Mt. Pinatubo. There were also major increases in ozone in the early years of World War 2 (letters w) and at the times of some other major explosive events.

There is typically a peak in ozone the year of each volcanic eruption. In the case of the Eyjafjallajökull eruption in 2010, a major emission of ozone occurred on February 19 (Fig. 4), just as magma at depth began moving toward the surface (Fig. 5).

There is much to learn and discuss about how ozone depletion appears to be the primary cause of global warming throughout Earth history.

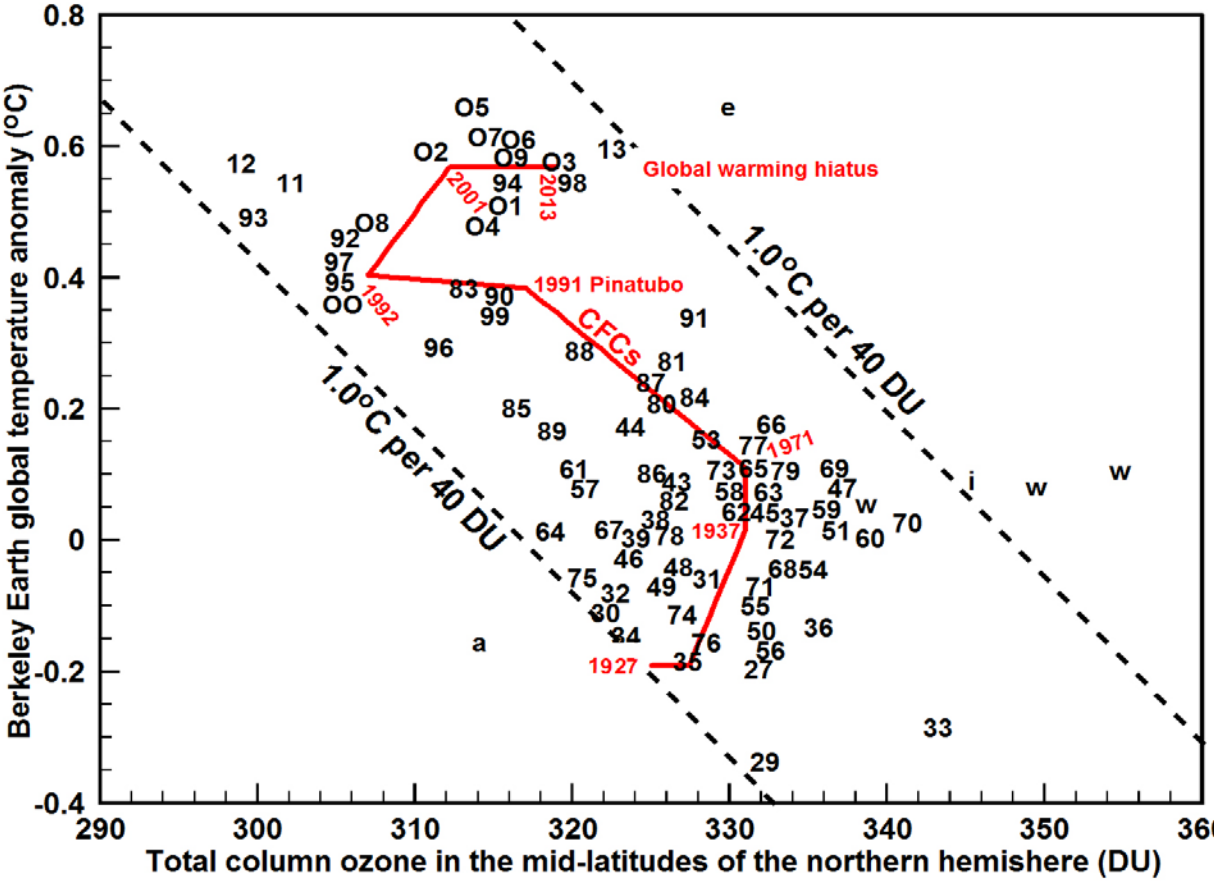

Fig. 3. For every 40 Dobson Units (DU) of depletion of ozone, annual global average temperature anomalies appear to increase approximately 1.0ºC shown most clearly from 1971 to 1991 when ozone depletion was caused primarily by CFC gases. Numbers are the years of the data points. The red line shows the trends in temperature (Fig.1) plotted as a function of the trends in ozone (Fig.2) to aid in comparison of the data in these different forms. The largest volcanic eruption since 1912 was Mt. Pinatubo (VEI=6) in 1991, causing major ozone depletion by 1992 and 1993, with a slow recovery to 2001. There were also 7 eruptions with VEI=5 and more than 50 eruptions with VEI=4 during this period that caused similar but smaller changes explaining much of the scatter in data points. The global warming hiatus then lasted from 2001 through 2013. Major warming since 2014 is not shown because the ozone data are not yet available. The letter "e" is for 2010 when Eyjafjallajökull erupted and ozone was emitted (Fig.4).

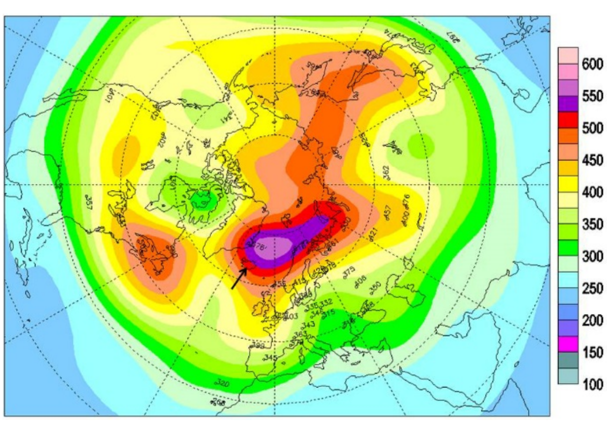

Fig. 4. Total column ozone northeast of Iceland increased to more than 550 DU on February 19, 2010, over a background of ~325 DU, an increase of ~70%. Arrow shows location of the volcano Eyjafjallajökull.

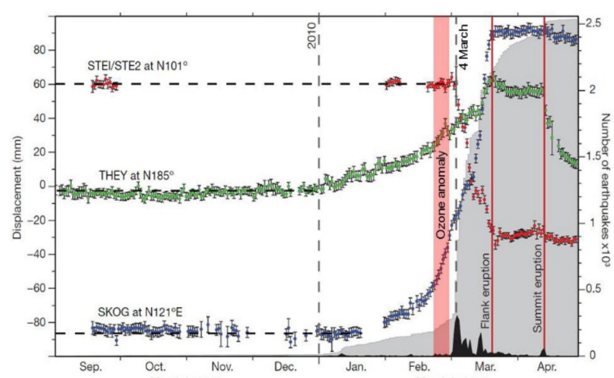

Fig. 5. Ground displacement and numbers of earthquakes shows that ozone emission from Eyjafjallajökull occurred just as magma began breaking to the surface (red region) from a dike at a depth of around 5.5 km (Sigmundsson et al., 2010).