Q18: Is depletion of the ozone layer the principal cause of climate change?

No, ozone depletion itself is not the principal cause of climate change. However, because ozone is a greenhouse gas, ozone changes and climate change are linked in important ways. Stratospheric ozone depletion and increases in global tropospheric ozone that have occurred in recent decades both contribute to climate change. These contributions to climate change are significant but small compared with the total contribution from all other greenhouse gases. Ozone and climate change are indirectly linked because ozone-depleting gases, such as the chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), and halons, also contribute to climate change.

Ozone depletion is not the major cause of climate change, but ozone changes are linked to climate change in important ways.

Radiative forcing of climate change. Human activities have led to the accumulation in the atmosphere of several long-lived and radiatively active gases known as "greenhouse gases." Ozone is a greenhouse gas, along with carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and halogen source gases. The accumulation of these gases changes the radiative balance of Earth's atmosphere. The balance is between incoming solar radiation and outgoing infrared radiation. Greenhouse gases generally change the balance by absorbing outgoing radiation, leading to a warming at Earth's surface. This change in Earth's radiative balance is called a *radiative forcing of climate change*. If the total forcing from all gases becomes large enough, climate could change in significant ways. A summary of radiative forcings resulting from the increase in long-lived greenhouse gases is shown in ***Figure Q18-1***. All forcings shown relate to human activities. Positive forcings lead to *warming* and negative forcings lead to *cooling* of Earth's surface. The accumulation of carbon dioxide is the largest forcing term. Carbon dioxide concentrations are increasing in the atmosphere primarily as the result of the burning of coal, oil, and natural gas for energy and transportation. The atmospheric abundance of carbon dioxide is currently about 30% above what it was 150 years ago in preindustrial times.

Stratospheric and tropospheric ozone. Changes in stratospheric and tropospheric ozone both represent radiative forcings of climate change. Stratospheric ozone absorbs solar radiation, which heats the stratosphere and affects air motions and chemical reactions. Stratospheric and tropospheric ozone both absorb infrared radiation emitted by Earth's surface, effectively trapping heat in the atmosphere below. Overall, the depletion of stratospheric ozone represents a negative radiative forcing. In contrast,

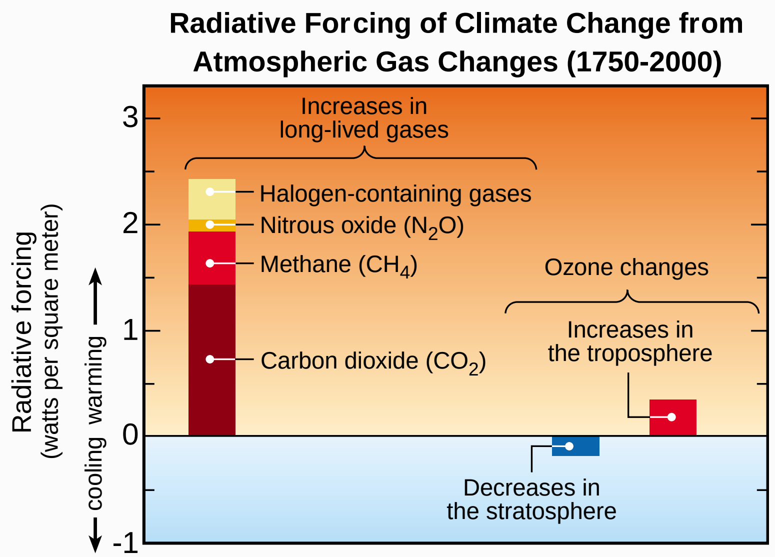

Figure Q18-1. Climate change from atmospheric gas changes. Human activities since 1750 have caused increases in the abundances of several long-lived gases, changing the radiative balance of Earth's atmosphere. These gases, known as "greenhouse gases," result in *radiative forcings*, which can lead to climate change. The largest radiative forcings come from carbon dioxide, followed by methane, tropospheric ozone, the halogen-containing gases (see ***Figure Q7-1***), and nitrous oxide. Ozone increases in the troposphere result from pollution associated with human activities. All these forcings are positive, which leads to a warming of Earth's surface. In contrast, stratospheric ozone depletion represents a small negative forcing, which leads to cooling of Earth's surface. In the coming decades, halogen gas abundances and stratospheric ozone depletion are expected to be reduced along with their associated radiative forcings. The link between these two forcing terms is an important aspect of the radiative forcing of climate change.

increases in tropospheric ozone due to surface pollution represent a positive radiative forcing. The radiative forcing due to tropospheric ozone increases is larger than that associated with stratospheric ozone depletion. Both forcing terms are significant, but are small in comparison with the total forcing from all other greenhouse gases.

Halogen source gases. An indirect link between ozone depletion and climate change is the radiative forcing from halogen source gases. These gases, which include chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), and halons (see ***Figure Q7-1***), are radiatively active in the atmosphere before they are chemically converted in the stratosphere. As a group, they represent a significant positive radiative forcing. Once converted, they form reactive halogen gases, which chemically destroy ozone. In the coming decades, halogen gas abundances and their associated positive radiative forcings are expected to decrease (see *Q16*). With reduced halogen gases, stratospheric ozone depletion and its associated negative radiative forcing will also be reduced. This link between these two forcing terms is an important aspect of the radiative forcing of climate change.

HFCs. The radiative forcing of halogen-containing gases in ***Figure Q18-1*** also includes that of the HFCs, which do not cause ozone depletion. The HFCs are increasing in the atmosphere because of their use as substitute gases for the CFCs and other halogen gases. HFCs are not regulated under the Montreal Protocol, but are included in the group of gases listed in the Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCC).

Climate change. Certain changes in Earth's climate could affect the future of the ozone layer. Stratospheric ozone is influenced by changes in temperatures and winds in the stratosphere. For example, low temperatures and strong polar winds both affect the extent and severity of winter polar ozone depletion. While Earth's surface is expected to warm in response to the positive radiative forcing from carbon dioxide increases, the stratosphere is expected to cool. Indeed, a small cooling of the lower stratosphere has occurred since the 1970s. A cooler stratosphere would extend the time period over which polar stratospheric clouds (PSCs) are present in polar regions and, as a result, might increase winter ozone depletion. These changes could delay the recovery of the ozone layer. In the upper stratosphere at altitudes above PSC formation regions, a cooler stratosphere is expected to increase ozone amounts. Changes in atmospheric composition that lead to a warmer climate may also affect the balance of production and loss processes of stratospheric ozone (see *Q20*).