Long term changes in the ionosphere over Indian low latitudes: Impact of greenhouse gases

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Increased concentration of greenhouse gases due to anthropogenic activities warm the troposphere and have a cooling effect in the middle and upper atmosphere. Ionospheric densities and heights are affected due to cooling. Carbon dioxide is one of the most dominant gases for the cause of long term ionospheric trends along with other radiatively active greenhouse gases. Regular ionospheric soundings are made over Ahmedabad (23.1°N, 72.7°E), since 1953. Long term changes in the ionosphere as a consequence of the cooling of the mesosphere and thermosphere due to the increased concentration of greenhouse gases have been studied. Ionospheric observations over Ahmedabad, a low latitude station in the anomaly crest region, for the years 1955–2003 are examined to study the long term changes in the critical frequencies of the various ionospheric layers and the height of the maximum ionization as characterized by hMF2. A decrease in LF2 (1.9 MHz for midday, 1.4 MHz for midnight) and hMF2 (18 km for midday, 17 km for midnight) during about five decades are noted. An increase is noted in LF1 (0.4 MHz). The LF2 data are also examined over an equatorial station Kodaikanal (10.2°N, 77.5°E), situated near the magnetic equator for the years 1960–1995 and a decrease of 0.5 MHz for midday and 0.7 MHz for midnight are noted in ~35 years.

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1. Introduction

In the recent years there has been a great concern over the increase in the concentration of the greenhouse gases due to anthropogenic causes, and the consequences in the global climate (warming). The 0.6 K increase in global temperature during the twentieth century (e.g., Intergovernmental Panel on Climate Change (IPCC), 2007) has been attributed mostly to the increasing atmospheric concentration of greenhouse gases. These gases cause warming in the lower atmosphere and an opposite, cooling effect in the upper atmosphere. Brasseur and Hitchman (1988) modeled the effect of increased carbon dioxide up to about 70 km and found that cooling rather than warming would be present near the stratopause. This effect of greenhouse gases on the upper atmosphere has been referred to as “greenhouse cooling” (Cicerone, 1990).

Roble and Dickinson (1989) were the first to demonstrate that the mesosphere and thermosphere would cool by 10 K and 50 K respectively due to a doubling of carbon dioxide (CO2) and methane (CH4) by using a global mean model of the mesosphere, thermosphere and ionosphere. They also reported that the ionospheric structure would alter with the lowered E and F region peaks due to the compositional redistribution that will occur in association with the change in temperature profile.

Further modeling studies by Rishbeth (1990), and Rishbeth and Roble (1992) broadened these results to the thermosphere–ionosphere system. Rishbeth (1990) examined the changes in the ionosphere due to the global cooling on the basis of the basic theory of ionosphere for mid latitude during equinox under quite geomagnetic and solar minimum condition. According to his calculations the cooling and associated compositional changes as described by Roble and Dickinson (1989) would lower the E and F2 layer peaks by ~2 km and ~20 km, respectively. Later Rishbeth and Roble (1992) considered the effect of global cooling using the three dimensional TIGCM (Thermosphere/Ionosphere General Circulation Model) developed at NCAR for both solar minimum and maximum conditions during December solstice. The results obtained for different latitudes and longitudes showed, on an average, reduction of hMF2 by 10–20 km for solar minimum and 10–15 km for solar maximum. The changes in E region were less than 0.5 MHz. They also studied the changes in electron density as a function of height and latitude. The largest changes were seen to occur in the F1 layer near 180 km with 50% increase at mid...