Geophysical Research Abstracts, Vol. 9, 00040, 2007
SRef-ID: 1607-7962/gra/EGU2007-A-00040

Overall Pattern of Global Change in the Upper Atmosphere

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The purpose of this talk is to inform climatological community on current climate change in the upper atmosphere (h $>$ 50 km), where the increasing concentration of greenhouse gases causes cooling, not heating, as confirmed by the "super-greenhouse" effect at planet Venus. The increasing concentration of greenhouse gases evokes significant changes in the upper atmosphere, i.e. in the mesosphere, thermosphere and ionosphere, including thermal contraction of these layers. The thermosphere is the operating environment of many communication and weather satellites, as well as the International Space Station, and knowledge of the atmospheric drag exerted on these objects is necessary for accurate prediction of their location. The structure of the ionosphere directly affects the performance of the GPS navigational system, whose signals are phase-shifted by ionospheric plasma. Thus long-term global changes of the upper atmosphere may affect space technologies we are increasingly dependent on.
Information about long-term trends in various upper atmospheric parameters has accumulated to a level such that a coherent pattern of upper atmospheric climate change is beginning to emerge. We present the first overall pattern (overall in parameters and height, not in geographic coverage) of global change in the upper atmosphere. The picture we obtain is qualitative, and contains several gaps and a few discrepancies, but the overall pattern of observed long-term changes throughout the upper atmosphere is internally consistent and consistent with model predictions. The dominant driver of long-term trends in the last 3-4 decades is increasing greenhouse forcing, although there may be contributions from anthropogenic changes of the ozone layer and long-term increase of geomagnetic activity throughout the 20^{th} century. Together with the large body of lower atmospheric trend research, our synthesis indicates that

anthropogenic emissions of greenhouse gases are affecting the atmosphere at nearly all altitudes between ground and space.

The global temperature at the Earth's surface increased by 0.2-0.4^{o}C over the last three decades, compared to a 5-10^{o}C decrease in the lower and middle mesosphere. Summer-winter differences of mid-latitude land surface temperatures are typically 25-30^{o}C, which is comparable to the seasonal and 11-year solar cycle variability of the mid-latitude mesosphere. Thus the signal-to-noise ratio of the trends is much higher in the mesosphere than at the surface.