Geophysical Research Abstracts
Vol. 18, EGU2016-9290-1, 2016
EGU General Assembly 2016

On applicability of the photochemical-equilibrium approach for retrieval of O and H mesospheric distributions from the satellite-based measurements of the airglow emission and ozone concentration

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Atomic oxygen and hydrogen are known to be among key components for the photochemistry and energy balance of the Earth's atmosphere between approximately 80 and 100 km altitude (mesopause region). Therefore, obtaining information about the vertical distributions of O and H concentrations is an important task in studies of this region. Solving of this problem is rather difficult due to the absence of regular methods which allow one to direct measurements of distributions of these components in mesosphere.
However, indirect methods used to retrieve O and H distributions from the satellite-based measurements of the OH and O_2(1D) airglow emission, as well as the data of IR and microwave O_3 measurements have a sufficiently long development history. These methods are rooted in the use of the condition of photochemical equilibrium of ozone density in the range of altitudes from 50 to 100 km. A significant factor is that an insufficient volume of such measurement data forces researchers to use approximate ("truncated") photochemical-equilibrium conditions. In particular, it is assumed that in the daytime the ozone production reaction is perfectly balanced by ozone photodissociation, whereas during the night the only ozone sink is the reaction of ozone with atomic hydrogen, which, in its turn, leads to formation of excited OH and airglow emission of the latter.
The presentation analyzes applicability of the photochemical-equilibrium conditions both in the total and truncated forms for description of the spatio-temporal evolution of mesospheric ozone during a year. The analysis is based on year-long time series generated by a 3D chemical transport model, which reproduces correctly various types of atmosphere dynamics in the range of altitudes from 50 to 100 km. These data are used to determine statistics of the ratio between the correct (calculated dynamically) distributions of the O_3 density and its uncontracted and truncated equilibrium values for the conditions of the daytime and nighttime mesosphere depending on the altitude, latitude and a month in the annual cycle. The studies performed yielded the following results:
1. The uncontracted daily condition of photochemical ozone equilibrium is fulfilled well (with an average deviation and relative dispersion of nor more than 1-3%) during the entire annual cycle within the entire range of altitudes and latitudes.
2. The truncated daily condition of photochemical ozone equilibrium is violated significantly at altitudes exceeding 70-75 km, where the deviation from the correct values of ozone density, which is averaged with respect to the longitude, local time, and month, can exceed 50% with a variance of 20-30%, and the spatial location of such "abnormal" zones is significantly dependent on the latitude and month.
3. The uncontracted nighttime condition of the photochemical ozone equilibrium is fulfilled satisfactorily (with a deviation and variance of less than 10%) in the range of altitudes from 80-85 km to 100 km.
4. The truncated nighttime condition of the photochemical ozone equilibrium is fulfilled satisfactorily at altitudes up to 90 km. However, at higher altitudes, the deviation of monthly values, which are averaged with respect to the longitude and local time, away from the correct ozone values can reach 20% and more.
The obtained results demonstrate that retrieval of O and H distributions by using truncated conditions of the photochemical ozone equilibrium can lead to significant uncontrolled errors. The presentation discusses possible modifications of the currently used approach, which allow one to improve the quality of retrieval of the O and H mesospheric distributions from the satellite-based probing of other mesosphere constituents.
The work was supported by the Russian Science Foundation (Contract No. 15-17-10024)