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Analysis of the synergetic ground-based MW+IR method for determining vertical profiles of ozone content

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Ozone is one of the important trace gases of the Earth's atmosphere, as the main absorber of dangerous UV radiation from the Sun, which has stimulated the creation and regular use of various methods for monitoring its content. Papers [1, 2] show that the use of joint MW and IR measurements increases the information content of remote ground-based sensing of the ozonosphere.

The report discusses a new ground-based method for determining the vertical profile of ozone (VP O_3), based on simultaneous MW and IR measurements (MW+IR). In addition, a method that combines measurements of two MW devices (MW + MW) is also considered. The following equipment operates at St Petersburg University (59.88˚ N and 29.82˚ E):

1. MW ozonometer measuring the spectrum of downward radiothermal radiation of the atmosphere in terms of brightness temperature (BT) in the region of the ozone absorption line 110.836 GHz;
2. MW radiometer HATPRO (Humidity And Temperature PROfiler), which has 7 spectral channels in the region of the water vapor absorption line of 22.235 GHz and 7 channels in the region of the oxygen absorption band of 60 GHz;
3. Fourier spectrometer (FS) IFS-125HR, performing measurements in the direct sun in the IR region of the spectrum with high spectral resolution (up to ~0.005 cm-1).

The characteristics of this equipment were used to simulate the spectra for the linear regression method. As an ensemble of atmospheric states, we used the ensemble prepared at the CNRM (Centre national de Recherches Météorologiques, France, https://iasi.aeris-data.fr/IASI-NG_4A_data/, access date: 05/10/2022) for the latitude zone 50-70˚ N.

Estimates of the errors in determining the VP O_3 were calculated with measurement errors in the MW region of 0.1-0.2 K and 1% in the IR region. These estimates show near 10 km the MW+MW method reduces the a priori uncertainty (AN) of ozone content from 65 to 45%, the MW+IR method - by 2 times. In the troposphere, the errors of the MW+IR method do not exceed 27%, in the 10-20 km layer - 17%. In the 20-40 km layer, the error estimate of the method is ~5-10%, in the 40-50 layer - 5-8% with an AN of 14-25%, above 50 km, an increase in the error estimate is observed along with an increase in the AH of the ozone content.

An important characteristic of the remote sensing method is its vertical resolution, which is usually defined as the width of the averaging kernel at half its maximum. Calculations of the MW + IR method averaging kernels were performed using a diagonal a priori ozone matrix. The half-widths of the averaging kernels are 10-20 km, and the high-altitude ceiling of the method’s sounding is ∼50-55 km.

Conclusions

1. Simulation has shown that joint measurements of the MW ozonometer and the HATPRO radiometer (MW + MW method) can reduce the error of retrieving in the altitude range of 9-16 km
2. Errors two times less than AH can be achieved at certain altitudes (9 km, 45 km) using simultaneous MW and IR measurements
3. Combining the MW and IR methods leads to an increase in the range of heights for which a decrease in AN is observed when retrieving a VP O_3
4. MW+IR method shows the best vertical resolution in the troposphere and lower stratosphere. In the troposphere, the vertical resolution is ∼10 km, in the stratosphere from 10 to 20 km

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