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Vertical profiling of methane and carbon dioxide using high resolution near-infrared heterodyne spectroscopic observations

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We present new method of monitoring greenhouse gases using spectroscopic observations of solar radiation passed through the atmosphere with spectral resolution $\lambda v \delta\lambda$ up to 10^8. Such a high resolution is achieved by heterodyne technique and allows to retrieve full information about spectral line shape which, in turn, is used to distinguish contribution of different atmospheric layers to the resulting absorption. Weak absorption line at 6056.5 cm^{-1} was selected for CO_2 measurements and a quartet of lines centered at 6057 $cm^{-1}$for CH_4.

The instrument setup includes Sun tracker with a microtelescope and chopper, diode DFB laser used as a local oscillator, a bundle of single mode optical fibers that provides medium for radiation transfer and beam coupling, reference cell with depressurized methane for LO frequency stabilization, and Fabry-Perot etalon for LO frequency calibration. A commercial p-i-n diode with squared detector replaces a mixer and IF spectrometer, providing measurement of heterodyne beating within a bandpass of few MHz, which determines the effective spectral resolution of the instrument. Spectral coverage within narrow range (about 1 cm^{-1}) is provided by ramping the LO frequency based on feedback from the reference channel.

Observations of Sun in the Moscow region have resulted for the first time in measurements of the atmospheric transmission near 1.65 μm with sub-Doppler spectral resolution. In order to retrieve vertical profiles of methane and carbon dioxide we developed the inversion algorithm implementing Tikhonov regularization approach. With measured transmission having S/N ratio of 100 or higher, the uncertainty of CH_4 profile is about 10 ppb, with the uncertainty of CO_2 profile at 1 ppm. This techniques is promising an affordable opportunity or widespread monitoring of greenhouse gases and may be implemented on existing ground-based stations.

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