to first guess methane vertical profile and the best fit to data, are presented by blue and red curves, respectively. In spite of strong pressure broadening in the troposphere, not only the shape of the methane feature allows to estimate overall column abundance of the absorber, but also to distinguish variations in its vertical distribution. In particular, profile with more abundant stratospheric methane would result in more distinct double-tip character of the CH_4 feature due to increasing contribution of less broadened absorption lines, as shown in Fig. 5(b). The retrieved methane profile [Fig. 5(c)] demonstrates higher mixing ratio in the first scale height compared to the assumed model profile, well expected in the megalopolis center [22–24].

In the upper part of the profile, where the data reveal weak sensitivity to methane abundance, retrieved profile approaches the first guess values due to regularization procedure described above. However, the reference to first guess profile is not the only source of uncertainty in the retrieved profile. To estimate its sensitivity to the uncertainty in both measured and synthetic transmittance spectra we repeated the retrieval procedure with random perturbations in data within one sigma level (about 0.01 in terms of transmittance) and in the assumed thermal profile within 5 K. 100 test retrievals have been made with each type of perturbations. The resulting variability in the retrieved profile is shown in Fig. 5(d) in terms of one-sigma RMS variations. Retrieved profile variations corresponding to perturbed data are shown by magenta curves, and those corresponding to perturbed temperature profile - by black curves. In both cases of perturbations the retrievals sensitivity is limited by 10 ppb, with the exception of the lower part of the profile where the tendency to lower values is revealed. Thus the methane abundance variations may be evaluated with relative accuracy much better than 1%, which fits the requirements of greenhouse gas monitoring.

5. Conclusions

The experiment described in this paper has proven feasibility of heterodyne detection in the near infrared range using commercial tunable diode laser as local oscillator and single mode fiber optics for beam combining. By means of heterodyne technique, a completely resolved methane absorption feature in the atmosphere has been measured in the solar occultation mode with RMS uncertainty equal to ~0.008 at net exposure time of 10 min. A minimal detectable signal of 10^{-21} W/Hz is expected, with the accuracy being limited by double shot noise level. Achieved spectral resolution is determined by LO line width and stability and constitutes about 2.5 MHz, which corresponds to resolving power of $\lambda/\delta\lambda \sim 10^8$. Due to higher spectral resolution, lower sensitivity to atmospheric temperatures, humidity and vibrations, compared to heterodyne measurements in the thermal IR spectral range, the technique described in this paper provides accuracy comparable with much more complicated high resolution measurements now used in TCCON stations. Higher spectral resolution, longer integration time and broader spectral coverage achieved due to LO stabilization by means of an external reference gas cell provides certain advantages compared to recently published examples of NIR heterodyne spectro-radiometry [10,11], in particular, the capability of absorber vertical profiling. Relative simplicity of the proposed scheme opens a perspective to employ this scheme for high resolution spectroscopy in various applications. In particular, it may allow solar occultation observations of CO_2, CO, CH_4, H_2S, C_2H_4 and other gases from spacecraft, airborne or ground-based platforms.

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