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Development of numerical model of laser sensing of clear air turbulence (CAT) taking into account effects of the propagation of laser radiation in a random medium, molecular and aerosol scattering

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We've built a numerical model of the propagation and scattering of laser radiation in a turbulent medium, taking into account molecular and aerosol scattering. The model will be based on the method of random phase screens. In the framework of this method, the direct propagation of laser radiation is modeled by the method of stepwise splitting. For this purpose, a random medium is divided into layers, and each layer is presented as a composition of an infinitely thin phase screen and vacuum propagation. To simulate a random medium, random phase screens whose phase thickness is associated with the spectrum of random medium inhomogeneities will be used.

Modeling incoherent (molecular and aerosol) scattering is based on the principle of reciprocity. Since the Green function for the propagation problem in a random medium is symmetric with respect to the permutation of the source and receiver, the backscattering problem can be reduced to solving the direct radiation propagation problem. In this case, the summation of the contributions of elementary random scatterers are performed in an incoherent manner.

In 2009–2015, with the support of the Commission of the European Communities, as part of the 7th framework program, the DELICAT project (DEmonstration of Lidar based Clear Air Turbulence detection) was carried out. In the course of this project, a lidar was designed, manufactured and tested for installation on an airplane with the aim of early detection of clear sky turbulence. The emitted signal was polarized vertically. The scattered radiation was measured in two polarizations: vertical and horizontal. The experiment showed that the effects of aerosol scattering at given altitudes can almost never be neglected.

To build an aerosol scattering model, the experimental data from the DELICAT project was analyzed. Spectral and cross-spectral analysis of measurements in two polarizations is already performed. Cross-spectral analysis will evaluate the effects of radiation depolarization. A model of the aerosol scattering matrix describing the observed effects of depolarization was constructed. In particular, multicomponent models will be considered. The spatio-temporal properties of aerosol clouds are closely investigated and also contribution of variations in the measurement geometry

during the flight to measurement errors.

The constructed numerical model shall make it possible to plan similar experiments in the future and better understand the role of aerosol and molecular scattering in the interpretation of experimental data in order to detect clear sky turbulence.

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