Case 7: Lidar pulses in optically thick clouds

Synposis

- Case 7 experiments simulate the 3D spread of laser pulses in optically thick clouds, caused by multiple scattering.
- The experiments allow detailed testing of models developed either for simulations of reflectance in lidar applications, for simulations of pathlength-dependent transmission in oxygen A-band spectroscopy, or for general 3D radiative transfer calculations.
- Participants can calculate either the temporal or the spatial dependence of reflected and transmitted signals, or both. They can provide these dependencies either explicitely or through statistical quantities such as the mean path and/or mean horizontal displacement between entry and escape from the cloud.
- Case7 Stage 1 involves simulations for horizontally homogeneous clouds with simple vertical structure. The three-dimensionality of problem lies in the 3D spread of radiation inside the cloud. Because of the simple cloud structure, words are sufficient to describe all experiments. Only a scattering phase function file needs to be downloaded for Experiments 5 and 6.

Detailed description

- Case 7 Stage 1 experiments consider the spread of an instantaneous, point source laser pulse, which arrives vertically at the cloud, perpendicular to the cloud's flat horizontal boundary.
- The complexity of cloud structure increases for successive experiments and is described separately for each experiment.
- Unless noted otherwise, aerosol scattering and absorption, gaseous absorption, droplet absorption, Rayleigh scattering, and surface reflection are neglected.
- Unless noted otherwise, reflected and transmitted radiances should be calculated for the exact back scatter and forward scatter directions, respectively (that is, perpendicular to the illuminated or the opposite cloud boundary, respectively).
- Participants providing explicit radiance (I) values should preferably submit both spatial and temporal information ($I(r,ct)$), with r being the horizontal radial distance from the collimated point source at the cloud boundary, c being the speed of light, and t being the time between photons enter and leave the cloud—which makes ct the total path covered by the photons. If this is not practical, participants may submit integrated radiances as functions of time ($I(t)$) or radial distance ($I(r)$), or even just the overall average radiances (I).
- The submitted radiance values should be normalized as follows: The mean radiances of a temporal-spatial bin should be multiplied by pi and divided by the incoming laser energy and by the area covered by each radial bin. These normalized radiances are similar to the bidirectional reflectance functions (or simply reflectances) often used in passive remote sensing and indicate the flux that would be reflected or transmitted if the angular radiance distribution was isotropic over a hemisphere. (In our case no normalization is needed regarding the angle of incidence, as the collimated point source beam arrives perpendicularly to the cloud boundary.) Hence the physical units are: emerging radiative energy/ pulse energy / unit of path (in m) / unit of area (in m**2). Please note that radiances are based on the emerging radiative energy that is normalized by the area covered by each radial bin.
- Participants providing statistical parameters of lidar returns should submit the first few (up to 4) moments of radial positions and/or photon traveling times.
- Where needed, the speed of light should be assumed to be exactly 3*10**8 m/s.

Downloading scene parameters:

- Case 7 Stage 1 Experiments 5 and 6 require one input file (45 kB): I3RC_Case7_Step1_phase_fn.txt
- This ASCII text file describes a cloud droplet scattering phase function calculated for 532 nm wavelength using Mie theory, for a lognormal drop size distribution with 10 μm effective radius and with a standard deviation that is 0.3 times the mean radius. The file contains two columns: one for the scattering angles (°) and the other for the corresponding phase function values.

Description of experiments:

- Experiment 1: Homogeneous, semi-infinite cloud. Extinction coefficient is 40 km-1, single scattering albedo is 1, and isotropic scattering is assumed.
- Experiment 2: Same as Experiment 1, but a Henyey-Greenstein phase function with *g* = 0.85 is assumed.
- Experiment 3: Same as Experiment 2, but particle single scattering albedo is 0.98.
- Experiment 4: Same as Experiment 2, but cloud geometrical thickness is 500 m. As a result, cloud optical thickness is 20.
- Experiment 5: Same as Experiment 4, but the provided Mie scattering phase function is used.
- Experiment 6: Same as Experiment 5, but the cloud extinction coefficient varies linearly with altitude, decreasing from 80 km-1 at the edge illuminated by the lidar to 0 km-1 at the opposite edge of the cloud.

Output files:

- Participants may choose to submit explicit radiance values and/or statistics values.
- Participants providing explicit radiance values are requested to submit up to four files for each experiment. The first one or two files should contain the simulated reflected and/or transmitted radiance values. The other one or two files should contain the estimated absolute (not relative) uncertainty of simulated radiance values.
- All file names should start with "I3RC_Case7_", then include the experiment ID (e.g., "Exp2_"), a 5-digit model ID (including 4 digits for institution), and end with either "Refl.txt", "Tran.txt", "UncR.txt", "UncT.txt", "StaR.txt", or "StaT.txt" to identify reflected or transmitted radiances, associated uncertainties, and statistics files, respectively. Using this convention, a sample file name would be "I3RC_Case7_Exp3_UMBC1_Refl.txt".
- Submitted radiance and uncertainty files should contain 512 rows and 256 columns in ASCII text format. Each row should represent a different pathlength (i.e., time) bin, and each column should represent a different radial distance bin. Pathlength resolution should be 30 m (corresponding to a time-resolution of 100 nsec or a range-resolution of 15 m for direct back scatter), radial resolution should be 10 m. Pathlength bins should reflect the path traveled (i.e., the time elapsed) between photons entering and leaving the cloud, and radial bins should reflect the horizontal distance between the photon's entry and exit points at the cloud boundary.
- Participants providing path-averaged (i.e., time-averaged) or space-averaged results should fill values only in the first row or column and put zeros into all other rows or columns. Accordingly, participants submitting overall average radiances should have only one non-zero value in each submitted file.
- If models can provide information on temporal and/or spatial dependence, but only at a coarser resolution, please provide results at 2, 4, 8, 16, 32, 64, or 128 times coarser resolution than the ones specified above. In this case the same values should be repeated many times in the output file, which should still contain 512 rows and 256 columns at 30 m pathlength (or 100 nsec time) and 10 m radial resolution.
- Submitted statistics files should contain 4 rows and 2 columns in ASCII text format. The first column should contain the first 4 moments of the pathlength distribution of radiance values (in m); the second row should contain the first 4 moments of the radial distance distribution of radiances (in m). If fewer than 4 moments are calculated, the undetermined values should be set to zero.
- The statistical moments for Experiments 1 and 2 are divergent, and so their values are infinite. Therefore participants may want to submit statistics results only for experiments 3-6.