Finnish Workshop on Radiative Transfer

Finnish Meteorological Institute, Erik Palménin aukio 1, Dynamicum-building, Helsinki

May 6-7, 2019

Organizers

Tanja Tarvainen (University of Eastern Finland), Hannakaisa Lindqvist (Finnish Meteorological Institute), Antti Penttilä (University of Helsinki)

Description

This workshop is arranged to bring together researchers working on theory and computational modelling of radiative transfer in Finland. The research fields include, but are not limited to, for example astronomy, atmospheric physics and biomedical optics. The aim is to gather together from these different fields to present their research and exchange ideas.

Schedule

	Monday 6.5.2019
10:15	Opening
10:30–11:00	Karri Muinonen: Radiative transfer in planetary regoliths: theory and experiments
11:00–11:30	Antti Penttilä: Radiative transfer in planetary regoliths: applications
11:30–12:00	break
12:00–12:30	Antti Arola: Radiative transfer modeling activities in FMI Atmospheric Radiation group
12:30–13:30	lunch (at own cost)
13:30–14:00	Jouni Peltoniemi: Radiative transfer in layered heterogeneous media, experiments and modelling
14:00–14:30	Matti Mõttus: Spectral invariants in vegetation reflectance modeling
14:30–15:00	coffee
15:00–15:30	Igor Meglinski: Current progress in computational imitation of radiative transfer: from simple light to complex vector laser beams
15:30–16:00	Tanja Tarvainen: Radiative transfer in light based tomography
16:00–16:15	break
16:15–17:00	Visit to FMI

	Tuesday 7.5.2019
9:00–9:30	Mika Juvela: Radiative transfer modelling of the interstellar medium
9:30–10:00	Jukka Kujanpää: Atmospheric radiative transfer model Siro and its applications
10:00–10:30	Hannakaisa Lindqvist: Light scattering by atmospheric particles: From fascinating model details to a challenge in space-based greenhouse gas retrievals
10:30–11:00	break
11:00–11:30	Petri Räisänen: On the computation of apparent direct solar radiation
11:30–11:45	Alexander Bykov: Selected problems of radiative transfer in optical biomedical diagnostics
11:45–12:00	Viktor Dremin: Monte Carlo simulation of diffuse reflectance spectra for quantitative assessment of physiological properties of human skin
12:00-12:15	Alexey Popov: Biotissue-mimicking phantoms for biophotonics applications
12:15–13:00	lunch (at own cost)
13:00–14:00	discussion
14:00–15:00	Visit to University of Helsinki scattering laboratory

Abstracts

Radiative transfer modeling activities in FMI Atmospheric Radiation group

Antti Arola, Pekka Kolmonen, Antti Lipponen
Finnish Meteorological Institute

The radiative transfer (RT) modeling activities in the FMI Atmospheric Radiation group are related to the atmospheric radiative transfer. We model the RT of light from ultraviolet (UV) to shortwave infrared. Our focus is on the atmospheric aerosols and UV radiation. The RT models are mostly used in the development of satellite retrieval algorithms that are inverse algorithms that are used to estimate the atmospheric properties given the satellite observed top-of-atmosphere radiances. There is a long experience, starting from 2007, to develop algorithms to retrieve aerosol properties (e.g. aerosol optical depth, AOD) using measurements from dual view instruments of ATSR-2, AATSR and SLSTR, earliest measurements starting from 1995. Currently, our algorithms are also adapted within the ESA FLuorescence Explorer mission (FLEX), planned to be launched in 2024. We are also starting a project to provide the official EUMETSAT aerosol product.

The FLEX work from our part is concentrated on the atmospheric correction which is a demanding task as the fluorescence signal is very small when compared to other TOA contributions. The correction for atmospheric aerosols and water vapor is to be carried out utilizing instruments (SLSTR, OLCI) on-board the Sentinel-3B satellite. The aerosol correction will be done with our ATSR-2/AATSR/SLSTR algorithm, but the radiative transfer requirements are quite different as the fluorescence instrument will be a very high-resolution spectrometer sensing in the Oxygen A and B regions.

One recent activity, in which RT modeling has been utilized, has been aerosol retrieval development work applied algorithm for the Moderate Resolution Imaging Spectroradiometer (MODIS) measurements (Lipponen et al. 2018) in collaboration with NASA. Due to high computational costs of RT models, typically a pre-computed lookup-table-interpolation based RT models are used in these aerosol retrieval algorithms. Recently related to the aerosol retrieval algorithm development, we have also started to develop computationally efficient but accurate surrogate RT models based on, for example, neural networks.

FMI has taken the leading role in the research, development and processing of satellite-UV and has been the only institute hosting the currently operational algorithms for many years. To support this development work, extensive experience in RT modeling (particularly focusing on UV wavelength range) has been gained.

For our applications we have mostly applied the following RT models:
LibRadtran http://www.libradtran.org/
DAK (Doubling-Adding KNMI)
MODTRAN (MODerate resolution atmospheric TRANsmission)

Selected problems of radiative transfer in optical biomedical diagnostics

Alexander Bykov
University of Oulu

Probing of biotissues with light has several significant advantages over the conventional methods of clinical diagnostics. In particular, optical methods are considered to be safe, non-invasive and often contactless. However, the peculiarities of light propagation in biotissues are often hinder the practical implementation of these methods.

Current report is a review of the numerical approaches aiming at evaluation and improvement of the sensitivity and applicability of several optical biomedical techniques developed and utilized in Optoelectronics and Measurement Techniques Laboratory of the University of Oulu. Specifically, we shall consider the adaption of Monte Carlo algorithm for modelling of radiative transfer in scattering media for biomedical optics applications and discuss the implementation of this algorithm for modelling of Optical Coherence Tomography (OCT), Doppler OCT [1], spatially resolved reflectometry, time domain, and frequency domain techniques [2].

In particular, using the developed approach to simulate OCT and Doppler OCT signals, it was demonstrated that in the case of low scattering, the scattering cross section, anisotropy, and flow velocity profile can be estimated from the Doppler OCT signal. For high scattering media, the slope of the OCT signal is strongly affected by the multiple scattering and the reconstructed flow velocity profile appears distorted. The deviation of the OCT slope from the value predicted by the single scattering model and the distortions in the measured flow velocity profile were analysed using the developed Monte Carlo model.

The applicability of spatial resolved reflectometry, time domain, and frequency domain techniques for the blood glucose sensing was also evaluated with the help of Monte Carlo method. The effect of glucose on the output signal of the considered techniques was numerically assessed. It was shown that the maximum sensitivity to variations in the glucose concentration within the physiological range in the three-layer tissue model considered in the study is observed for the source-detector separation equal to 0.4 mm. In this case, the maximal relative change of the detected signal is about 8% or 0.016% per mg/dl (relative change of the detected signal caused by the change in the glucose concentration of 1 mg/dl). The maximal possible sensitivity among the considered methods was observed for the time-of-flight technique. In this case, the relative sensitivity reaches the value of about 12% (or 0.024 % per mg/dl).

References:
1. A.V. Bykov, J. Kalkman, "Analysis of Doppler optical coherence tomography signals in low and high scattering media". In "Handbook of coherent-domain optical methods: biomedical diagnostics, environmental monitoring, and material science", Ed. V.V. Tuchin, Springer (2013).
2. A.V. Bykov, M. Yu. Kirillin, A.V. Priezzhev, "Monte Carlo simulation of light propagation in human tissues and noninvasive glucose sensing". In "Handbook of Optical Sensing of Glucose in Biological Fluids and Tissues", Ed. V.V. Tuchin, Taylor & Francis (2008).

Monte Carlo simulation of diffuse reflectance spectra for quantitative assessment of physiological properties of human skin

Viktor Dremin, Evgeny Zherebtsov, Alexander Bykov, Alexey Popov, Igor Meglinski
University of Oulu

Presently, the optical to near-infrared spectral characterization of biological tissues are of a considerable interest in frame of new sensors development. The theory of radiation transfer deals with the diffuse intensity of light and is widely used for description of light-tissue interaction. Due to the complex structure of tissue and, respectively, boundary conditions, one of the most popular solution of radiative transfer equation is the stochastic Monte Carlo (MC) technique. It has been shown that MC approach can quite realistically imitate the propagation of light within biological tissues.

We utilize unified object oriented MC model, developed in-house, which allows describing photons and structural components of biological tissues as the objects interacting to each other. Thus, the core of our modeling methodology is focused on the computational observation of how an object-photon propagates through an object-medium and interacts with its constituents, mimicking in such way an interaction with cells, blood vessels, collagen fibers, etc. Such a representation of the medium by objects makes it possible to develop comprehensive 3D tissue models with the required spatial variations of malformations. To achieve the optimal modelling performance, we use a parallel computing framework CUDA (NVIDIA Corporation).

In particular, for the simulation of skin diffuse reflectance, we have developed a seven-layer tissue model. The model takes into account the absorbing and scattering properties of the skin. Absorption coefficients of the layers are calculated by taking into account concentration of blood volume fraction in skin, blood oxygen saturation, hematocrit, water content, melanin fraction, and fat content. The scattering coefficient of a particular layer is represented by a combination of Mie and Rayleigh theories. The model also takes into account the anisotropy factor and the refraction index of the layers.

The developed approach was successfully applied for hyperspectral assessment of physiological properties of the skin. To solve the inverse problem of estimation of skin chromophore content, a neural network approach was used. A training set of spectra for the neural network was modelled by the MC method. The combination of a fast hyperspectral camera, neural network-based processing and MC simulation allowed for multiparameter estimation of tissue properties. The devel-oped technique has potential applications in monitoring and diagnostics of diabetic ulcer formation and other relevant skin diseases along with cosmetological defects.

Radiative transfer modelling of the interstellar medium

Mika Juvela
University of Helsinki

Our understanding of astronomical sources is based mainly on radiation. This is true also in studies of the interstellar medium (ISM) where we observe the emitted, scattered, and extincted radiation from sources with a wide range of optical depths. The objects are typically extended clouds (diameters 1e14 m or more) of gas and dust where the properties of the ISM itself can be highly dependent on the radiation field. Our main interests are in the interactions of radiation with interstellar dust grains and with interstellar molecules, as they are observed at large scales.

The extinction, scattering, and thermal emission of interstellar dust are standard tools in the study of the structure of star-forming interstellar clouds. Conversely, the observations reveal an evolution in dust properties between diffuse clouds and dense, pre-stellar cores. I will describe some ongoing research on the modelling of dust scattering and emission. I will also discuss the challenges in the radiative transfer post-processing of magnetohydrodynamical models where the number of discrete volume elements is approaching one billion.

In the case of spectral lines, the basic radiative transfer methods are often simpler. This is because scattering (as a process changing the direction of photon propagation) can normally be ignored. On the other hand, the radiation changes the excitation state of the atoms and molecules, which again changes the optical depth of the medium. Therefore, more than in the case of dust studies, calculations may require a large number of iterations before an equilibrium solution is reached. I will discuss some of the methods that are used to control the noise of the solution and to speed up the convergence.

Atmospheric radiative transfer model Siro and its applications

Jukka Kujanpää, Erkki Kyrölä
Finnish Meteorological Institute

In this presentation we describe the atmospheric radiative transfer model Siro and show examples of its use at the Finnish Meteorological Institute. Siro is a statistical Monte Carlo model simulating the photon paths backwards from the detector to the source. This approach is effective in a typical application where the detector is a narrow field of view satellite instrument and the source, the Sun, has a very wide field of view. The Monte Carlo approach has many benefits: various physical processes can relatively easily be included in the simulation, the sphericity of the atmosphere can readily be taken into account and the simulated photon paths provide valuable information on the contribution atmospheric constituents on the measured spectrum. In our applications, radiative transfer model is typically needed as a forward model for inversion algorithms to derive atmospheric content from a remotely measured spectrum. Challenges in using a statistical forward model in atmospheric inversion problems are also discussed.

Light scattering by atmospheric particles: From fascinating details to a challenge in space-based greenhouse gas retrievals

Hannakaisa Lindqvist
Finnish Meteorological Institute

Atmospheric aerosol particles and cloud constituents scatter and absorb solar radiation. These effects can be taken into account in radiative transfer considerations but that requires models for the optical properties of these particles for the relevant wavelengths. Atmospheric particles are rich in sizes, morphology and composition, which is often necessary to consider in their optical models. These particles affect also retrievals of other atmospheric constituents through changes in the light paths. While these effects may have been previously neglected, they are becoming increasingly important as retrieval accuracy requirements increase.

My talk in this workshop addresses this wide topic from three perspectives. First, I will give a brief overview on the optical modeling of atmospheric aerosol particles, with an emphasis on non-spherical particles and modeling their optical properties. Second, I will talk about solving light scattering by large, absorbing particles using ray optics with a consideration for inhomogeneous waves. This method is directly applied to atmospheric ice crystals in the near-infrared wavelengths. Third, I will introduce the importance of considering aerosol effects in space-based greenhouse gas retrievals with practical examples using retrievals from the Nasa Orbiting Carbon Observatory -2.

Current progress in computational imitation of radiative transfer: from simple light to complex vector laser beams

Igor Meglinski
University of Oulu

Based on the comparison of the iteration procedure of the solution of Bethe-Salpeter equation and the Monte Carlo method, a unified computational method for imitation of radiative transfer in complex tissue-like turbid medium has been developed. The developed approach is comprehensively validated and verified against diffusing theory, exact Milne solution, alternative theoretical models and the results of experimental studies. It has been demonstrated that the developed computational technique is able not just simulate, but imitate the results of actual experiments. The technique was generalized and extensively used in major applications in biophotonics and biomedical imaging, and since recently actively utilized for new sensors design. Current presentation comprises a brief description of the background of the approach, and shows the examples of the results, including simulation of coherent effects of multiple scattering of laser radiation, such as enhancement of Coherent Back-Scattering (CBS) and temporal intensity fluctuation of polarized laser radiation scattered within the random inhomogeneous turbid medium, modeling of circularly polarized light propagation in biological tissues and pilot results of imitation of angular momentum of light (Laguerre-Gaussian twisted or structured light) transfer in turbid tissue-like scattering medium.

Radiative transfer in planetary regoliths: theory and experiments

Karri Muinonen, Timo Väisänen
University of Helsinki

Theoretical, numerical, and experimental methods are described for radiative transfer in macroscopic discrete random media of densely-packed microscopic particles. The theoretical and numerical methods constitute a framework of Radiative Transfer with Reciprocal Transactions (R^2T^2). The R^2T^2 framework entails Monte Carlo order-of-scattering tracing of interactions in the frequency space, assuming that the fundamental scatterers and absorbers are wavelength-scale volume elements composed of large numbers of randomly distributed particles. The discrete random media are fully packed with the volume elements. For spherical and nonspherical particles, the interactions within the volume elements are computed exactly using the Superposition T-Matrix Method (STMM) and the Volume Integral Equation Method (VIEM), respectively. For both particle types, the interactions between different volume elements are computed exactly using the STMM. As the tracing takes place within the discrete random media, incoherent electromagnetic fields are utilized, that is, the coherent field of the volume elements is removed from the interactions.

The experimental methods [4] are based on acoustic levitation of the samples for non-contact, non-destructive scattering measurements. The levitation entails full ultrasonic control of the sample position and orientation, that is, six degrees of freedom. The light source is a laser driven white-light source with a monochromator and polarizer. The detector is a mini-photomultiplier tube on a rotating wheel, equipped with polarizers. The R^2T^2 is validated using measurements for a mm-scale spherical sample of densely-packed spherical silica particles.

[1] Muinonen K, Markkanen J, Väisänen T, Peltoniemi J, and Penttilä A (2018). Multiple Scattering of Light in Discrete Random Media Using Incoherent Interactions. Optics Letters 43(4), 683–686.

[2] Markkanen J, Väisänen T, Penttilä A, and Muinonen K (2018). Scattering and absorption in dense discrete random media of irregular particles. Optics Letters 43(12), 2925–2928.

[3] Väisänen T, Markkanen J, Penttilä A, and Muinonen K (2019). Radiative transfer with reciprocal transactions: Numerical method and its implementation. PLOS ONE 14(1), 1–24.

[4] Maconi G, Penttilä A, Kassamakov I, Gritsevich M, Helander P, Puranen T, Salmi A, Haeggström E, and Muinonen, K (2018). Non-destructive controlled single-particle light scattering measurement. JQSRT 204, 159–164.

Spectral invariants in vegetation reflectance modeling

Matti Mõttus
VTT Technical Research Centre of Finland

Vegetation reflectance models rigorously follow the transfer of shortwave radiation in plant canopies. The models differ mainly in the implementation method of the radiation transfer and the approach in quantifying the canopy. In the most simple and already classical approach, the vegetated layer is described as a continuous layer of infinitesimally thin plates – leaves – with predefined orientation. Most detailed models use 3D raytracing and an explicit tree structure model. A compromise in detail and computing speed are the so-called geometric-optical models which describe a vegetation canopy (or, specifically, a forest) as a set of geometric objects, tree crowns.

The foundations of the 'spectral invariants theory' were put forth as a new tool to model the shortwave radiation absorbed or scattered by vegetation nearly two decades ago. According to this theory, the amount of radiation absorbed, reflected or transmitted by a vegetation canopy should, to a great accuracy, depend only on the spectral albedo of canopy elements – leaves – and one or more wavelength-independent parameters quantifying the structure of the canopy. Later, the theory has been extended to the scale smaller than the leaf. The optical properties of a vegetation canopy in the visible and near infrared spectral regions has been demonstrated to largely depend on the absorption spectrum of chlorophyll and a nested set of spectral invariants – an invariant for each structural level (leaf, shoot, tree, canopy). In using abstract canopy levels, spectral invariants are well matched with geometric-optical canopy reflectance models with additional structural levels inside a crown envelope. Other spectral invariants have been introduced to quantify the directionality of canopy scattering. The invariants have their mathematical roots in the eigenvalues of the radiative transfer operator, supporting their application in structurally and optically varying vegetation covers. The spectral invariant – or a set of nested invariants – describing absorption is closely connected to the photon recollision probability. This largely intuitive quantity can be estimated from optical measurements of canopy structure and easily modeled with any modern physically-based canopy radiative transfer model. It has been successfully applied in the simple canopy reflectance model called PARAS and scaling of optical properties between different scales: from needle to the canopy.

We demonstrate some of the applications of the spectral invariants and photon recollision probability in global and local monitoring of vegetation using spectral data. It is especially useful in a boreal forest with distinct levels of clumping, but it is also fully compatible with the two-stream approach in canopy reflectance modelling. The full potential of the theory of spectral invariants, allowing to separate the biochemical and structural components in the spectral reflectance signal of vegetation, is yet to be unleashed.

Radiative transfer in layered heterogeneous media, experiments and modelling

Jouni Peltoniemi
Finnish Geospatial Research Institute FGI, National Land Survey

We have measured the reflectance of numerous samples using our old field goniospectrometer FIGIFIGO. We have recently build a smaller desktop goniopolarimeter to measure smaller samples in higher accuracy in laboratory. We can now measure the linear polarisation, and soon the full Muller matrix of reflected radiation.

The results from new and old system agree rather well in the first test samples, and confirm the inaccuracies are not alarming in neither instrument. The new one should have much better polarisation accuracy.

We have upgraded our old models to a new composition. Small particulate sublayers are initialised using Monte Carlo ray tracing. These sublayers are doubled for quasihomogeneous layers of arbitrary thickness. Several different layers can be added to form the full layered medium. The particles are modelled as rough ellipsoids. The surfaces or interiours of particles can be covered by small point scatterers, here computed using Monte Carlo based volume integral equation technique.

The model agrees rather well with the measurement data of snow, sand, and gravel. There are still some minor details in forward polarisation needing furher attention. Next, rough top layers will be returned to the model and compared to measurements, and then we implement more complex 3D structures, when we get more measurements from targets with controlled structures.

Radiative transfer in planetary regoliths: applications

Antti Penttilä, Julia Martikainen
University of Helsinki

Computational light scattering methods applicable to many size scales are needed to solve the light scattering problems typical in planetary sciences. Especially, we are focused on the photometric, polarimetric, ans spectroscopic properties of atmosphereless, small Solar System bodies, i.e., asteroids, comets, dwarf planets, and moons. With these, the modeling starts from the nanometer-micrometer scale with the scattering properties of the dust grains on the surface of these objects (called regolith), or in the coma of comets. The size scale continue with optically large surface elements consisting of close-packed particulate random material all the way to the disk-integrated observations of a whole (one/ten/hundred) kilometer-sized objects.

Due to the large size scales needed, we also need to develop and use many different light scattering methods. The smallest scales will need explicit Maxwell equations solvers such as Mie, volume- or surface-integral methods. The next scales cannot be handled with exact Maxwell solvers, so we need to employ both physical/geometrical optics and radiative transfer (RT). We have developed Monte Carlo RT methods to handle close-packed random media[1,2,3].

In this talk, we will present some examples of how we apply and tie together these different methods into a multi-scale modeling approach that can predict spectral, photometric, and polarimetric properties of asteroids[4]. We will also introduce our laboratory measurement capabilities and how they link to the modeling[5].

[1] Muinonen K, Markkanen J, Väisänen T, Peltoniemi J, and Penttilä A (2018). Multiple Scattering of Light in Discrete Random Media Using Incoherent Interactions. Optics Letters 43(4), 683–686.

[2] Markkanen J, Väisänen T, Penttilä A, and Muinonen K (2018). Scattering and absorption in dense discrete random media of irregular particles. Optics Letters 43(12), 2925–2928.

[3] Väisänen T, Markkanen J, Penttilä A, and Muinonen K (2019). Radiative transfer with reciprocal transactions: Numerical method and its implementation. PLOS ONE 14(1), 1–24.

[4] Martikainen J, Penttilä A, Gritsevich M, Videen G, Muinonen K (2018). Absolute spectral modeling of asteroid (4) Vesta. MNRAS 483(2), 1952–1956.

[5] Penttilä A, Martikainen J, Gritsevich M, Muinonen K (2018). Laboratory spectroscopy of meteorite samples at UV-vis-NIR wavelengths: Analysis and discrimination by principal components analysis. JQSRT 206, 189–197.

Biotissue-mimicking phantoms for biophotonics applications

Alexey Popov, Alexander Bykov, Igor Meglinski
University of Oulu

Increasing importance of noninvasive biomedical diagnostics and minimally invasive therapy opens new horizons for photonic technology and leads to development of novel optical methods and devices. An important step in this development is validation of the designed systems, methods and models. Thus, stable samples with well-controlled optical properties that closely match those of biological tissues are required for this testing step. No standard optical phantoms are commercially available up to date.

We show our progress in manufacturing biotissue-mimicking phantoms made from different materials.

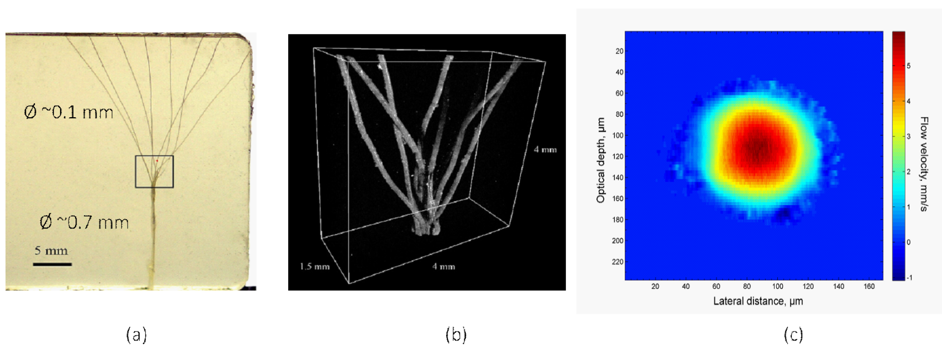

Figure 1: Manufactured capillary system in a transparent phantom layer (a). For the better visibility the channels were made in transparent layer and filled with the Intralipid 4%. 3D optical coherence tomography (OCT) image of the capillary tree filled with Intralipid 4% (b). The imaged area corresponds to the black rectangle shown on the left picture. The diameter of the vessels is of 0.1 mm. Map of the Intralipid flow velocity profiles measured with Doppler OCT technique inside the capillary marked with red dot in the leftmost figure (c).

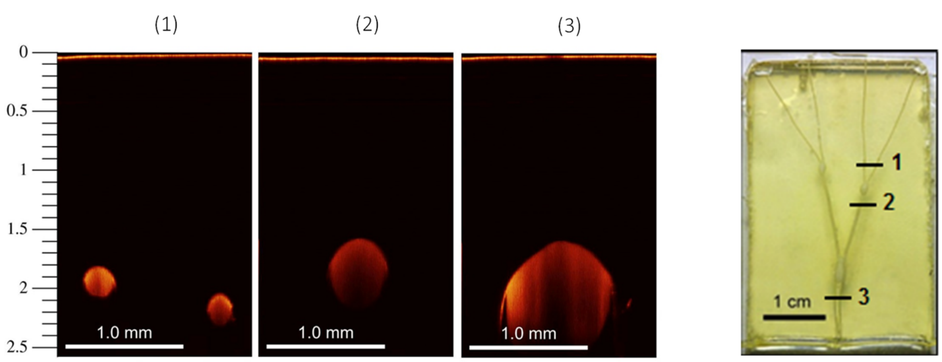

Figure 2: OCT images of the capillaries in a transparent phantom layer filled with Intralipid 4%.

On the computation of apparent direct solar radiation

Petri Räisänen, Anders V. Lindfors
Finnish Meteorological Institute

Near-forward-scattered radiation coming from the vicinity of Sun's direction impacts the interpretation of measurements of direct solar radiation by pyrheliometers and sun photometers: a substantial part of the measured "direct" radiation can actually be scattered radiation. This issue is also relevant for concentrating solar power applications. Here, a Monte Carlo radiative transfer model is employed to study the apparent direct solar transmittance $t(\alpha)$, that is, the transmittance measured by an instrument that receives the radiation within a half-field-of-view (half-FOV) angle α from the centre of the solar disk, for various ice cloud, water cloud and aerosol cases. The contribution of scattered radiation to $t(\alpha)$ increases with increasing particle size, and it also depends strongly on ice crystal shape and roughness. The Monte Carlo calculations are compared with a simple approach, in which $t(\alpha)$ is estimated through Beer's law, using a scaled optical depth that excludes the part of the phase function corresponding to scattering angles smaller than α. Overall, this optical depth scaling approach works very well, although with some degradation of the performance for ice clouds for very small half-FOV angles ($\alpha < 0.5 - 1\,\text{deg}$), and in optically thick cases. The errors can be reduced by fine-tuning the optical depth scaling factors based on the Monte Carlo results. It is also shown that the optical depth scaling used in delta-two-stream approximations employed in numerical weather prediction and climate model radiation calculations is inappropriate for simulating the direct solar radiation received by pyrheliometers.

Radiative transfer in light based tomography

Tanja Tarvainen
University of Eastern Finland

There is an increasing interest in developing tomographic imaging modalities based on visible or near-infrared light. This interest in utilising light in biomedical imaging arises from benefits of light based modalities: sensitivity to tissue oxygenation, simple and low-cost instrumentation, non-invasive nature and usage of non-ionising radiation. Examples of such techniques include, for example, diffuse optical tomography, fluorescence optical tomography and (quantitative) photoacoustic tomography. Image reconstruction in tomographic imaging modalities is an ill-posed inverse problem. Solution of such problem requires accurate solution of the forward model describing physics of the imaging situation. Conventionally, optical tomographic techniques rely on simplified models for light propagation in tissue, such as diffusion approximation or modifications of the Beer-Lambert law. However, a more accurate model of light propagation in these imaging situations is the radiative transfer equation. In this talk, I give a short review on light based tomographic methods and modelling aspects related to these techniques. Furthermore, I briefly tell about the work that we have done in Kuopio regarding this topic.

Participants

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