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Preface

Two Truly Special Sessions at the *2009 International Conference on Mathematics and Computational Methods* (*M&C* 2009): Transport … Across Disciplinary Divides

This Special Issue of the *Journal of Quantitative Spectroscopy and Radiative Transfer* assembles 13 papers that have grown out of two sessions convened at the International Conference on Advances in Mathematics, Computational Methods and Reactor Physics (M&C 2009) held May 3–7, 2009, in Saratoga Springs, New York. It was sponsored by the American Nuclear Society (ANS) and, in particular, includes the topical meeting organized biannually by its Mathematics and Computation Division.[1] The ANS's M&C meetings cover a very broad range of topics: transport theory of course, with applications to many things nuclear (-engineering, -medicine, -astrophysics, etc.), but also reactor physics, reactor design, multiphysics simulation, and so on.

One of these two sessions, a specially organized one, was focused on "Radiation Transport in the Earth Sciences;" the other, a more standard occurrence in the ANS M&C meeting series, was about "Transport in Stochastic Media" and was chaired by one of us (RS). The other one of us (AD), a veteran of geophysical meetings but new to ANS meetings, had previously contributed to the Stochastic Media session at M&C 2007, and this interaction lead to being guest convener for the Earth Sciences session in 2009.

The stated goal of the Earth Sciences session was to bring as many North American radiative transfer theoreticians as possible from their native geophysical applications to an ANS meeting where transport theory is in the spotlight. At an ANS meeting, transport theory will be concerned primarily with neutrons of course and secondarily with gammas and X-rays as well as electrons, neutrinos and other subatomic particles. However, if the fundamental equation of interest is seen purely as a mathematical construct, the exact nature of the transported particles or energy is immaterial for many technical aspects of the theoretical and computational problem. This was an excellent opportunity for Earth scientists to exchange ideas with nuclear scientists and engineers using a common mathematical language. Well, maybe we are talking about two dialects of the same language, as we illustrate further on.

By its very nature, the Earth Science session was populated primarily with invited papers (6 out of 7 total) given by individuals that the convener (AD) had known for years. With the above-stated session goal in mind, he had personally approached these colleagues to make this experiment as interesting and diverse as possible. The session was well attended by an audience overwhelmingly dominated by members of the nuclear community, clearly very curious about other applications of transport theory and asking penetrating questions all along. That said, some of the Earth Science session convener's invitees ended up in the Stochastic Media session (3 out of 7 total). This cross-over rate can be viewed as a measure of how much commonality there is between transport theoreticians in different application areas. It was therefore decided that this Special Issue, although first discussed (pre-meeting) only within the author collective from Earth Sciences, would be open to contributions from all presenters at both topical sessions, irrespective of what community the authors identify with. Our hope is that this volume will be viewed at once as a reference, a cross-section of current topics in theoretical and computational transport, and as a memento of a successful grassroots effort at crossing a disciplinary divide to reach new heights.

Transport theory is inherently daunting. The core equation to solve has up to seven independent variables (3 for position, 2 for direction of propagation, 1 for particle energy or wavelength, and possibly 1 more for time dependence) and up to four coupled dependent variables in the case of polarized electromagnetic (EM) radiation. Moreover, transport processes play key roles in important multi-physics problems ranging from nuclear reactors, weapons and astrophysics to the Earth's climate system. Accuracy requirements in modeling nuclear engineering systems are of course far more stringent than in Earth system science applications. That is fundamentally why the Mathematics and Computation Division of the ANS is so highly dedicated to particle/energy transport. By contrast, the word "transport" in an Earth science context would most likely evoke an air quality concern, e.g., mid-level winds carrying

[1] See http://local.ans.org/ne-ny/topical_2009_neny.html for more information.

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dust or smoke over synoptic distances or the downwind dispersal of a chemical or radiological species. The linear Boltzmann equation would only come to mind within a small community of specialists. The term "radiative transfer" (RT) is used more readily in Earth science for this highly technical and specialized topic inside of which there is an even smaller and tighter "3D RT" community.

At any rate, it is important that RT experts in Earth science need not feel isolated by their passion for the linear transport/Boltzmann equation. It is our hope that future ANS M&C meetings will continue to attract non-nuclear transport theoreticians. We also hope to see more and more transport theoreticians trained in nuclear applications follow the path blazed by Sig Gerstl, Gerry Pomraning and other pioneers that crossed into Earth Science. We would also like to see more crosscutting workshops such as those convened at Granlibakken by Frank Graziani [1,2]. We salute in passing the free spirits such as Ed Larsen, Barry Ganapol and Norm McCormick that so easily move from one application area to another. Finally, there are new outlets for linear transport theory, particularly, in medical imaging technology and in computer-generated imagery that should be watched by all of the above. Accordingly, this special issue contains two papers written by authors engaged in each of these emerging applications.

The 13 papers submitted to this Special Issue naturally fall into two groups along the lines of the two special sessions at M&C2009. Both review and research papers were solicited. Like any other submission to this Journal, they were all rigorously peer-reviewed by two or more referees. Referees were recruited among the author collective as well as outside of it, depending on need. We hereby thank all the reviewers for their high-level remarks as well as their scrutiny of the details. We also thank the Chief Editors of the journal for enabling the Special Issue project, and their occasionally critical actions that made it advance. Finally, we acknowledge the unwavering support of the Elsevier Production Staff to the Guest Editors, and we can speak here on behalf of all of the authors as well. Without this help and encouragement, this community project never could have been brought to fruition.

The first seven papers result from the session on Stochastic Media, of which six come directly from talks. An additional one was contributed by two authors (Fichtl and Prinja) that could very well have given talks at that session. There is an interesting clustering and cohesiveness among these papers about whether or not the popular binary Markovian field model is adopted for the random spatial variability. In its original form, the probability of changing from one material to the other after taking a step in any direction is an exponential function of step size that depends conditionally only on what the present material is. With only two structural parameters to deal with, Markovian fields are serious contenders for modeling neutron transport in a new and interesting kind of nuclear reactor known as "pebble beds."[2]

[2] See http://en.wikipedia.org/wiki/Pebble_bed_reactor or http://www.cd-adapco.com/press_room/case_studies/060118_pebblebed.html for details.

The first trio of papers adopts this framework outright.

- We start with the review paper by Kassianov and Veron [3] who offer a broad survey of the binary Markovian model, from its historical origins to recent extensions and applications of the concept. The primary concern is the Earth's cloudy atmosphere, which has very different correlations in the horizontal and in the vertical. This stochastic transport model is attractive because it is, at least in certain limits, analytically tractable. It has therefore offered valuable insights into the transport effects of computationally and/or observationally unresolved random spatial structure.
- Greisheimer et al. [4] examine an important problem that is preliminary to RT or neutron transport computations in binary stochastic media when seen as "inclusions" in an "embedding" material. It has been shown that the RT can be expedited in a Monte Carlo scheme if the probability distribution function (PDF) of chord lengths through the inclusions is known. The authors compute this PDF explicitly for equally sized inclusions in 1D, 2D and 3D, including edge effects.
- Brantley [5] performed computations using three variants of the stochastic Monte Carlo technique as well as a standard deterministic approximation (the so-called "atomistic mix" limit of the Markovian field model). He compared the outcomes of two representative suites of binary mixture problems with benchmarks from the literature based on ensemble averages. Accuracy and efficiency are systematically assessed.

It will surprise no one that the binary Markovian mixture transport model was developed independently on both sides of the iron curtain. More interestingly, this work was apparently also performed on both sides of the application divide between atmospheric scientists in the Former Soviet Union [6] and nuclear scientists in the West [7–9]. But they were on a historical and geographical collision course. Georgii Titov, a key Markovian RT player from the Institute for Atmospheric Optics of the Siberian Branch of the Russian Academy of Sciences in Tomsk, emigrated to the US in the mid 1990s; around the same time, Gerry Pomraning from UCLA, an original developer of the famous Markovian "LP" model, proactively crossed over from nuclear to atmospheric applications. They quickly befriended each other before their premature deaths in the late 1990s.[3] Fig. 1 will bring warm feelings to all who knew these unusually charismatic human beings. We still miss them dearly.

For the record, we recall that research into transport in binary Markovian media has spawned a more general and useful approach to stochasticity effects in discrete finite media, namely, renewal probability theory [9,10]. That modeling framework retains the simplifying Markovian property but only for interface statistical sets and, in sharp contrast with its full Markovian limit, it is used routinely in practical reactor physics; in particular, it has enabled the

[3] We note that the academic lineages of the banner review's coauthors, E. Kassianov and D. Veron, trace back to these two individuals.