Syllabus of ATOC 525 Atmospheric Radiation

This course teaches graduate students and higher-level undergrad students the fundamental physical interactions between radiation and the atmosphere (i.e., the emission, absorption, and scattering processes), and the formulation and applications (e.g., satellite remote sensing) of the radiative transfer equation. The course consists of lectures and computer labs. The evaluation of the students includes homework assignments and a course project.

Objectives

1) Learn the physical laws that govern the emission, absorption and scattering of radiation;
2) Learn to mathematically and numerically describe the radiative transfer process;
3) Learn to analyze radiation data and to run radiation model.

Contents

1. Basics of the Earth atmosphere
   Vertical structure of the Earth atmosphere;
   Ideal gas law;
   Hydrostatic equation
2. Basics of radiation
   Electromagnetic radiation spectrum: Solar, terrestrial;
   Radiometric quantities;
   Blackbody radiation: Planck's Law, Stefan-Boltzmann's Law, Kirchhoff's Law
   Extinction Law and differential Radiative Transfer Equation (RTE)
3. Absorption and emission
   Fundamentals of molecular spectroscopy: Line position / intensity / shapes
4. Scattering
   Description of scattering: phase function and scattering cross section;
   Rayleigh and Mie scattering;
   Polarization
5. Non-scattering radiative transfer
   Plane-parallel atmosphere approximation;
   Integral RTE and weighting function;
   Heating rates;
   Exact (line-by-line) RT calculation and approximation methods
6. Scattering radiative transfer
   Exact solutions: discrete ordinates, adding
   Approximation methods: 2-stream, Eddington
7. Radiation and satellite remote sensing

Satellite orbits and instrumentation;
Nature of the inverse problem

8. Radiation and climate
   Radiative equilibrium;
   TOA radiation energy budget;
   Climate sensitivity, forcing and feedback

Evaluation Scheme

Homework assignments (50%)
Course Project (50%), including a proposal, a progress report, a final presentation and a final report. See the Appendix for the requirements of the course project.

References

- Lecture notes
  Available on myCourses
- Textbooks on atmospheric radiation/radiative transfer
  Bohren and Clothiaux, Fundamentals of atmospheric radiation;
  Coakley and Yang, Atmospheric radiation;
  Goody and Yung, Atmospheric radiation: theoretical basis;
  Liou, An introduction to atmospheric radiation;
  Petty, A first course in atmospheric radiation;
  Stephens, Remote sensing of the lower atmosphere: an introduction;
  Thomas and Stamnes, Radiative transfer in the atmosphere and ocean;
- Textbooks on atmospheric physics
  Houghton, The physics of atmospheres
  Salby, Fundamentals of atmospheric physics
  Wallace and Hobbs, Atmospheric science: an introduction

Disclaimer Concerning Integrity

- McGILL UNIVERSITY VALUES ACADEMIC INTEGRITY. THEREFORE ALL STUDENTS MUST UNDERSTAND THE MEANING AND CONSEQUENCES OF CHEATING, PLAGIARISM AND OTHER ACADEMIC OFFENCES UNDER THE CODE OF STUDENT CONDUCT AND DISCIPLINARY PROCEDURES
  (see www.mcgill.ca/integrity for more information).

Appendix: Requirements of the course project

During the course of the semester, you will be asked to submit these documents for your course project:

1) Proposal
In 3 paragraphs, describe:
a) Objective: what problem(s)/question(s) you will address/answer. Also describe your motivation: why the problem is important, how is it relevant to your (research) interests, etc.
b) Methodology: what model (and dataset) you will use. For the radiative transfer model, describe the model configuration: what are the key parameters pertinent to your project, how you will set and perturb them to obtain your desired results. For a dataset (if any), describe what relevant variables, time period and space domain you plan to investigate and what analysis methods, such as correlation, linear regression, EOF, etc., you will use.
c) Expected results: Typically, you can reference to results in the literature (published papers, reports and textbooks) and indicate which results (e.g., figures, tables, or equations) you aim at reproducing or verifying. Try to draw connection to the open questions that your work may help address.

2) Progress Report
Include one plot in this report and thoroughly describe it: what variable is plotted, what feature it has - is it expected or unexpected, and why?

3) Presentation:
You will each give an oral presentation on your project in the last week of the semester. 12-min presentation plus 3-min questions (15-min in total) each person. As a rule of thumb, prepare no more than 1 slide per minute (<=12 in total) when making your presentation. The order of your presenters is usually alphabetical according to your names. Please email your presentation to me or bring it with a USB before your presentation date.

It is important that everyone attends all the presentations (even when you don't give a presentation) and participates in the Questions/Answers discussions after each presentation. This is for everyone to receive respectful and useful comments from your classmates.

Refer to the rubrics enclosed below for what is considered a good presentation.

4) Final Report
Your report is due the last day of the semester (the day the classes end, prior to the start of the final exams).

Your report should consist of these sections: Introduction, Methodology, Results, Discussion, and References. The length, including all these sections, should be within 6 pages, with up to 4 figures and up to 3000 words (excluding the references). I would appreciate a print copy of this report for grading, besides a digital copy by email.

If you have got many results and like to include them in your report, put additional figures and texts to a Supplementary Information document. There is no length limit for this document. No need to print it. Just enclose it in the digital submission of your report.

Include in the digital submission of your report a supplementary information . This file or folder should include your program scripts (those you generated instead source codes of the RT models), input file (e.g., Tape5) for radiation model, etc. – in essence, all the materials needed to reproduce your results, except for the original data files and RT models. It would be helpful to include a readme file in the folder to document what is in each file. You can simply put these files into a folder, zip it and send together with your report by email or preferably a Dropbox/OneDrive link.

Evaluation rubrics is provided at the end of the Appendix.

1. Oral Presentation Rubric

Structure of presentation:
Unacceptable 0-2 points (disorganized contents, missing any of these key elements: Introduction, Method and Result), Acceptable 3 points (includes all key elements, but the description of some element is unclear), Good 4 points (clear description of all elements, insufficient discussion of result), Excellent 5 points (complete and balanced presentation of all elements, including good explanation of the results)

Graphical contents:
Unacceptable 0-2 points (small fonts, cluttered slides, unlabeled, inadequate references), Acceptable 3 points (generally adequate font size and labelling, but some slides are unclear and in need of improvement), Good 4 points (generally good graphical presentation, could be improvements in student generated figures or tables), Excellent 5 points (very good use of layout, figures, and fonts, including student generated figures that are publication-level quality)

Oral communication:
Unacceptable 0-2 points (long pauses, reading, poor audience engagement), Acceptable 3 points (fluent delivery, but reading or awkward delivery but not reading), Good 4 points (generally good delivery, but audience engagement could be improved), Excellent 5 points (clearly delivered, smooth without reading)

2. Final Report Rubric

Quality of the research (50/100):
Clearly identified objectives (as described in Proposal)?
Objective(s) met; question(s) posted answered?
Research plan fully executed?
Methods correctly applied?

Understanding of the results (30/100):
Results validated?
Main features in the results identified and described?
Correctly interpreted and/or related to radiation knowledge and theory?
Conclusions properly stated and supported by the results?

Quality of presentation (20/100):
Report properly structured (Intro/Method/Result/Discussion)?
Clarity of the method? Equations, model inputs/outputs and analytical programs explained?
Figures/tables sufficiently, logically and legibly included?
References included?