

# **Atmospheric Radiation**

ATS 622, Department of Atmospheric Science  
11:00 – 11:50 Tuesdays and Thursdays, Online/Hybrid

## ***Instructor Contact Information***

Prof Christine Chiu  
Christine.Chiu@colostate.edu  
ACRC 203  
Office hours: 1–2 pm Wednesday and 2–3 pm Thursday

## ***Teaching Assistant Contact Information***

Kevin Yang (yang0920@rams.colostate.edu)  
Office hours: 3 – 4 pm Monday and Tuesday

## ***Course Description***

This is an introductory graduate level course on fundamentals of electromagnetic radiation and the radiative properties/processes involving the atmosphere, aerosols, clouds, and precipitation. This course introduces crucial laws and mechanisms in radiation transfer; demonstrates how they drive and influence our climate system; and relates these fundamentals to well-defined research questions. The main teaching method is lectures, with assignments that aim to develop students' practical skills.

## ***Course Goals***

Students who complete this course successfully will be able to:

- Describe and explain theoretical principles of radiative processes, focusing on solar and terrestrial radiation.
- Quantify radiative effects, heating/cooling rates, and interpret their roles in the Earth's radiation energy budget.
- Apply knowledge of atmospheric radiation and develop radiative transfer simulations for relevant research topics.

## ***Course materials***

Lecture slides and detailed notes will be available on google drive (see the following link) in due course.

<https://drive.google.com/drive/folders/1d1jfbGzqqjHnrZejcFJld0o18pTYANVvk?usp=sharing>

The instructor uses the following textbooks (copies available in the library) to supplement lectures:

- Petty, G. W., 2006: A First Course in Atmospheric Radiation, Sundog Publishing, 472 pp., available from <http://www.sundogpublishing.com>.
- Liou, K.-N., 2002: An Introduction to Atmospheric Radiation, Academic Press, 583 pp.
- Coakley, J. and P. Yang, 2014: Atmospheric Radiation: A Primer with illustrative solutions, Wiley, 256 pp.

### ***Class Participation***

Students' participation and engagement are strongly encouraged. All interactions and discussions in the classroom are aimed to provide a supportive and active learning environment for students.

### ***Grading***

- Assignment 1: **10 points (written by individual)**
- Assignment 2: **15 points (written by individual)**
- Assignment 3: **15 points (oral by group)**
- Assignment 4: **20 points (oral by group)**
- Assignment 5: **10 points (written by individual)**
- Class Project **15 points (presentation) and 15 points (2-page written report)**

Homework will be due at the date and times indicated. No late homework assignments will be accepted without prior approval. Final exam is closed book and closed notes.

### ***Statement on Academic Integrity***

This course will adhere to the CSU Academic Integrity Policy as found in the General Catalog (<http://www.catalog.colostate.edu/FrontPDF/1.6POLICIES1112f.pdf>) and the Student Conduct Code (<http://www.conflictresolution.colostate.edu/conduct-code>). At a minimum, violations will result in a grading penalty in this course and a report to the Office of Conflict Resolution and Student Conduct Services.

### ***Disclaimer***

The instructor reserves the right to make modifications to this information throughout the semester.

**Preliminary Schedule of Topics and Assignments**

Week	Topics / Learning outcomes	Remark
1	<p><b>Logistics &amp; Overview</b></p> <ul style="list-style-type: none"> <li>• Why we should care about atmospheric radiation</li> <li>• Its relevance to meteorology, climate, remote sensing</li> </ul>	
1	<p><b>Properties of Radiation</b></p> <ul style="list-style-type: none"> <li>• Summarize the characteristics of electromagnetic radiation</li> <li>• Definition of irradiance, radiance and solid angle</li> <li>• Compute net flux and radiation for isotropic and general cases</li> </ul>	
2	<p><b>The Sun and solar radiation at the top of the atmosphere</b></p> <ul style="list-style-type: none"> <li>• Describe the structure of the Sun</li> <li>• Summarize key features of total solar irradiance</li> <li>• Compute solar insolation and describe how it varies with time and latitude</li> </ul>	
3 – 4	<p><b>Planck function</b></p> <ul style="list-style-type: none"> <li>• Explain the apply Planck function and related laws</li> <li>• Quantify global energy flow using window-gray approximation</li> <li>• Derive and compute radiative time constant</li> </ul> <p><b>Absorption, emission and scattering by a slab of atmosphere</b></p> <ul style="list-style-type: none"> <li>• Explain fundamental optical properties</li> <li>• Describe Beer’s law and perform Langley analysis</li> <li>• Formulate radiative transfer equation in plane-parallel atmosphere</li> </ul>	<p><b>Assignment #1 due in Week 3</b></p>
5 – 7	<p><b>Scattering and absorption by particles in the atmosphere &amp; Practical session 1</b></p> <ul style="list-style-type: none"> <li>• Define scattering regimes (Rayleigh scattering, Mie scattering, and geometric optics)</li> <li>• Describe main features of each scattering regime</li> <li>• Relate these scattering regimes to atmosphere radiation and remote sensing applications</li> </ul>	<p><b>Assignment #2 due in Week 6</b></p> <p><i>Practical session 1 in Week 6</i></p>

Week	Topics / Learning outcomes	Remark
8 –10	<p><b><i>Equation of radiative transfer and its solutions &amp; Practical session II</i></b></p> <ul style="list-style-type: none"> <li>• Distinguish between direct and diffusion radiation; between single scattering and multiple scattering processes</li> <li>• Apply single scattering approximation</li> <li>• Describe the underlying principle of the two-stream approximation and derive the two-stream solution</li> <li>• Summarize key features of cloud albedo, transmittance and absorptance</li> <li>• Explain the key points of the adding/doubling methods and apply them to radiative transfer</li> </ul>	<p><i>Practical session 2 in Week 8</i></p> <p><b><i>Assignment #3 due in Week 8</i></b></p>
11 – 12	<p><b><i>Absorption and emission by atmospheric gases</i></b></p> <ul style="list-style-type: none"> <li>• Explain why certain gases strongly absorb radiation at certain wavelengths</li> <li>• Describe properties of absorption lines and identify the broadening mechanisms responsible for the line shapes</li> <li>• Compare and contrast line-by-line models (LBL), the k-distribution and correlated k-distribution</li> <li>• Apply LBL and k-distribution to realistic atmospheric conditions for both shortwave and longwave radiative transfer</li> <li>• Compare and contrast various absorption band models, including the Elsasser model and the Goody model</li> </ul>	<p><b><i>Check point for class project in Week 11</i></b></p> <p><b><i>Assignment #4 due in Week 12</i></b></p>
13		<p><i>Spring Break</i></p> <p><i>No class</i></p>
14	<p><b><i>Radiative heating and cooling rate</i></b></p> <ul style="list-style-type: none"> <li>• Derive radiative heating equations</li> <li>• Provide physical interpretations for each term in radiative heating/cooling equations</li> <li>• Sketch shortwave and longwave heating profiles</li> </ul>	<p><b><i>Assignment #5 due in Week 14</i></b></p>
15	<p><b><i>The planetary radiation budget and the role of aerosols and clouds</i></b></p> <ul style="list-style-type: none"> <li>• Summarize key features/patterns of global annual mean radiation</li> <li>• Summarize key features/patterns of cloud radiative effects for the longwave, shortwave and net radiation</li> <li>• Describe the underlying processes of cloud radiative effects</li> </ul>	
16	<b>Project presentation</b>	<b><i>Report due on May 11.</i></b>