AST 455/555: Planetary Applications of Remote Sensing

College of the Environment, Forestry, & Natural Sciences
Department of Astronomy & Planetary Science

Semester:	Spring 2024
Prerequisites:	None
Location:	Lectures & Lab: Bldg. 19, Rm. 232
Meeting Time:	2:20pm-3:35PM, Lectures: Mondays, Labs: Wednesdays
Instructors:	Dr. Christopher Edwards, christopher.edwards@nau.edu, (928) 523-7234
	Dr. Alicia Rutledge, alicia.rutledge@nau.edu, (928) 523-5236
Office Locations:	Edwards: Bldg. 19, Rm. 205.
	Rutledge: Bldg. 20, Rm. 158
Office Hours:	Edwards: (M) 1:30-2:20 pm
	Rutledge: (W) 1:30-2:20 pm
	Both instructors are available by appointment upon request.

Google Drive: https://bit.ly/AST455-555-Student

Course Purpose:

This course will focus on the tools, techniques, and fundamental principles of the remote investigation of planetary surfaces and atmospheres. Particular emphasis will be placed on tracking energy from its source through its interactions with different forms of matter, its receipt by instruments of specific design, and its eventual processing and interpretation by humans on Earth. The majority of labs and exercises will be focused on the Earth, as data are widely available and easier to validate than more distant planetary bodies. Letter grade only.

Course Description:

Every human is a natural expert in the science of remote sensing. We use our eyesight, our hearing, our sense of smell, and our sensitivity to temperature to continually investigate our surroundings. This skill allows us to explore distant objects or properties without making direct contact with those objects. For example, we are able to enjoy the multitude of colors in fall foliage without analyzing the chemical composition of each individual leaf.

By exploiting the unique properties of the electromagnetic spectrum, we have developed instruments that are capable of remotely identifying and recording many different properties of Earth and space. We are able to measure the chemistry of forests, the surface temperature of Mars, and the surface roughness of desert landscapes using different types of energy. Each of these remote sensing systems, however, comes with their own limitations. How small of an object can you study? How accurate is your sensor? How frequently can you measure the same location?

In this class, you will learn the different properties of the electromagnetic spectrum and how each type of energy can be used to investigate our surrounding environment. You will also learn how data are collected, stored, and analyzed, both by the instruments themselves and by the humans that process and analyze the data. Lastly, you will learn the skills (and art) behind aerial/satellite image enhancement and interpretation, which transform the data into useful final products.

Throughout class, we will be using a powerful computer program known as *ENVI*. *ENVI* is a remote sensing and image processing software package developed for remote sensing applications by remote sensing experts themselves. You will quickly learn the fundamentals behind *ENVI* and will be tasked with using this software in nearly all class assignments.

Course Objectives & Learning Outcomes:

This course has several objectives and learning outcomes that will be addressed during lecture and assessed through in-class exercises, take-home lab assignments, and examinations. By the end of the semester, students in both AST 455 and AST 555 will be able to:

1. Demonstrate an understanding of the properties and characteristics of the electromagnetic spectrum and how they are used to understand the physical and chemical properties of materials (*CT*);
2. Describe how sensors record electromagnetic energy and how these records can be interpreted (*CT, C*);
3. Identify and discuss the utility and limitations of different wavelength ranges for different planetary applications (*CT, C*);
4. Explain and manually perform image processing and image manipulation techniques (*C, T*); and
5. Demonstrate proficiency in using image processing and remote sensing software to process, visualize, and manipulate remotely acquired data (*T, L*).

In addition to the course objectives and learning outcomes described above, students in AST 555 will also be able to:

6. Identify relevant research topics that can be addressed using remote sensing (*CT, CSD*); and
7. Develop independent research projects that utilize remote sensing data to investigate a hypothesis (*CSD, L, CT*).

Career Competencies & Transferable Skills:

The National Association of Colleges and Employers (NACE) defines eight Career Readiness Competencies - transferable skills that promote successful entrance into the workforce and lifelong career management. Each of our assignments provides practice developing these career competencies. They are:

1. *Career & Self-Development (CSD):* Proactively develop oneself and one's career through continual personal and professional learning, awareness of one's strengths and weaknesses, navigation of career opportunities, and networking to build relationships within and without one's organization.
2. *Communication (C):* Clearly and effectively exchange information, ideas, facts, and perspectives with persons inside and outside of an organization.
3. *Critical Thinking (CT):* Identify and respond to needs based upon an understanding of situational context and logical analysis of relevant information.
4. *Equity & Inclusion (EI)*: Demonstrate the awareness, attitude, knowledge, and skills required to equitably engage and include people from different local and global cultures. Engage in anti-racist practices that actively challenge the systems, structures, and policies of racism.
5. *Leadership (L):* Recognize and capitalize on personal and team strengths to achieve organizational goals.
6. *Professionalism (P):* Knowing work environments differ greatly, understand and demonstrate effective work habits, and act in the interest of the larger community and workplace.
7. *Teamwork (TW):* Build and maintain collaborative relationships to work effectively toward common goals, while appreciating diverse viewpoints and shared responsibilities.
8. *Technology (T):* Understand and leverage technologies ethically to enhance efficiencies, complete tasks, and accomplish goals.

Co-Convening of AST 455 and AST 555:

This course is co-convened between AST 455 and AST 555. Graduate students will be tasked with generating independent research proposals to separate the undergraduate and graduate offerings of this course. These differences will be incorporated into the ***Homework*** section of course assessment.

The goal of the undergraduate offering (AST 455) is to ensure that students have a strong foundation in remote sensing techniques, remote data generation, and the processing and interpretation of a variety of remote sensing datasets. This will be accommodated through focused homework assignments and guided assessments. The goal of the graduate offering (AST 555) is to develop and hone critical thinking skills and to facilitate the investigation of independent research hypotheses. Students will be able to critically evaluate differences between remote datasets and determine which type of data are most appropriate for a range of different desired studies. These skills will prepare graduate students for future independent research and proposal writing.

Assessment:

Course assessment will include in-class exercises, take-home laboratory assignments, three examinations (two midterms and one final), and professionalism and engagement in class. Unless discussed with the professor beforehand, late assignments turned in within 24 hours after it is due will be penalized with a 30% reduction in grade. Assignments turned in more than 24 hours late will not be accepted without prior approval.

In-Class Exercises (CSD, C, EI, TW): In-class exercises are designed to teach students how to put into practice the information that was previously discussed in lecture. These exercises will also help to familiarize students with the specific analytical techniques and how *ENVI* can be used in the context of this material. Students are encouraged to work collaboratively to complete these exercises, but to turn in their own assignments. The in-class exercises are worth a total of 250 points (25% of the total course grade).

Homework Assignments (CT, T): Homework assignments build upon the in-class exercises and are designed to test each student's analytical and problem-solving skills. Each lab will require students to generate digital products to document their progress and will also ask students to describe or discuss different components of the work. Graduate students will also be tasked with developing an independent research project as part of their homework assignments in the second half of class. Homework assignments are worth a total of 350 points (35% of the total course grade).

Examinations (CT, C, T): Three examinations will evaluate students' understanding of the fundamental concepts discussed in class as well as their ability to apply these principles to data generation, analysis, and interpretation using *ENVI*. Exams will not be cumulative. The exams are worth a total of 300 points (30% of the total course grade).

Professionalism & Engagement (CSD, P, EI, TW, L): Engagement in class is a critical part of the learning experience. Unless otherwise noted, students are encouraged to work together to improve their understanding of class materials and the image processing software. As a baseline, a student's professionalism and engagement grade will represent their average performance on in-class exercises, laboratory assignments, and examinations. Points can be deducted for habitual lateness, class interruptions, lack of effort, or academic misconduct. Oppositely, points can be added for engaging in discussions, attending office hours, and assisting fellow classmates, to name a few. Professionalism & Engagement is worth a total of 100 points (10% of the total course grade).

Grading System: The breakdown of points is as follows, and any changes to the class scoring rubric will be discussed with the class prior to implementation.

AST 455 (Undergraduate Offering):

In-Class Exercises	*250 points*
Homework Assignments	*350 points*
Examinations (three total)	*300 points*
Professionalism & Engagement	*100 points*
Total	***1,000 points***

AST 555 (Graduate Offering):

In-Class Exercises	*250 points*
Homework Assignments	*230 points*
Independent Research Assignment	*120 points*
Examinations (three total)	*300 points*
Professionalism & Engagement	*100 points*
Total	***1,000 points***

Your course grade will be based on the total points earned, and a letter grade will be assigned using the grading scale below:

A:	≥900 points	(≥90%)
B:	800 – 899 points	(80% – 89.9%)
C:	700 – 799 points	(70% – 79.9%)
D:	600 – 699 points	(60% – 69.9%)
F:	<600 points	(<60%)

Required Materials & Technology:

REQUIRED: No required course materials. Weekly reading materials will be provided to students via the course site on Canvas and Google Drive.

Course Schedule

Week	Date	Topic & Content	Materials Due	Required Readings
1	M 1/15	**No Class (MLK)**		
	W 1/17	Course Introduction		(a) 2.1-2.5, 2.8-2.9, Mustard (2017)
2	M 1/22	Fundamentals of Electromagnetic Radiation		
	W 1/24	Intro to ENVI and RS Data (*Exercise #1*)		(a) 2.6, (c) 1.1-1.2, Stephan et al. (2010)
3	M 1/29	Atmospheric Phenomena		
	W 1/31	Atmospheric and Surface Properties (*Exercise #2*)		(a) 2.7, 3.1, 3.4, (b) 2.6-2.7, Asner et al. (2012)
4	M 2/5	Energy and Radiance at Sensor		
	W 2/7	Surface Phenomena		
5	M 2/12	Sensor Properties		(c) 2.2.3, Rogalski (2002, p61-95), Rogalski (2012)
	W 2/14	Resolution (*Exercise #3*)	**HW #1**	
6	M 2/19	"Create Your Own Sensor" (HW #2 Work Session)		
	W 2/21	**Exam #1**		
7	M 2/26	Vibrational Absorptions		Clark (1999)
	W 2/28	Vibrational Absorptions (*Exercise #4*)	**HW #2**	
8	M 3/4	Electronic Absorptions		
	W 3/6	Electronic Absorptions (*Exercise #5*)		
9	M-W 3/11	***Spring Break, No Class***		
10	M 3/18	Thermophysics		Fergason et al. (2006), Presley & Christensen (1997), Piqueux & Christensen (2009)
	W 3/20	Thermophysics (*Exercise #6*)	**HW #3**	
11	M 3/25	Thermophysics (cont.)		(a) 5.1-5.2, 5.4-5.5, Lawrence et al. (1998), Viviano-Beck et al. (2014, *sections 4-7*), other
	W 3/27	Parameterization, Band Math, etc. (*Exercise #7*)	**HW #4**	
12	M 4/1	Other Techniques		
	W 4/3	**Exam #2**		
13	M 4/8	Intro to Signal Processing		Gillespie et al. (1986), (c) 2.5, (d) Ch. 5, *other*
	W 4/10	Advanced Signal Processing		
14	M 4/15	Image Classification, Color Transformations		
	W 4/17	Data Manipulation (*Exercise #8*)	**HW #5**	
15	M 4/22	Student Presentations #1		Bandfield et al. (2000), Greenhagen et al. (2010), Rockwell & Hofstra (2008), Bowen et al. (2007); Dunn et al. (2010)
	W 4/24	TIR Applications (*Exercise #9*)		
16	M 4/29	Student Presentations #2		Mustard et al. (2008), Cheek et al. (2011), Kruse et al. (1990, Cuprite), Donaldson Hanna et al. (2014); Bandfield & Feldman (2008)
	W 5/1	VNIR Applications (*Exercise #10*)	**HW #6 Due**	
17	Tu 5/7, 3:00-5:00pm	**Exam #3**		

Textbooks:

(a) Introduction to Satellite Remote Sensing, Emery & Camps, 2017;
(b) Remote Sensing Digital Image Analysis, 2006;
(c) Optical Remote Sensing of Land Surfaces, Baghdadi & Zribi, 2016;
(d) Principles of Remote Sensing, Tempfli et al., 2001

SYLLABUS POLICY STATEMENTS

ACADEMIC INTEGRITY
NAU expects every student to firmly adhere to a strong ethical code of academic integrity in all their scholarly pursuits. The primary attributes of academic integrity are honesty, trustworthiness, fairness, and responsibility. As a student, you are expected to submit original work while giving proper credit to other people's ideas or contributions. Acting with academic integrity means completing your assignments independently while truthfully acknowledging all sources of information, or collaboration with others when appropriate. When you submit your work, you are implicitly declaring that the work is your own. Academic integrity is expected not only during formal coursework, but in all your relationships or interactions that are connected to the educational enterprise. All forms of academic deceit such as plagiarism, cheating, collusion, falsification or fabrication of results or records, permitting your work to be submitted by another, or inappropriately recycling your own work from one class to another, constitute academic misconduct that may result in serious disciplinary consequences. All students and faculty members are responsible for reporting suspected instances of academic misconduct. All students are encouraged to complete NAU's online academic integrity workshop available in the E-Learning Center and should review the full *Academic Integrity* policy available at https://www9.nau.edu/policies/Client/Details/1443?whoIsLooking=Students&pertainsTo=All

ARTIFICIAL INTELLIGENCE
Artificial intelligence (AI) technologies bring both opportunities and challenges. Ensuring honesty in academic work creates a culture of integrity and expectations of ethical behavior. The use of these technologies can depend on the instructional setting, varying by faculty member, program, course, and assignment. Please refer to course policies, any additional course-specific guidelines in the syllabus, or communicate with the instructor to understand expectations. NAU recognizes the role that these technologies will play in the current and future careers of our graduates and expects students to practice responsible and ethical use of AI technologies to assist with learning within the confines of course policies.

COPYRIGHT INFRINGEMENT
All lectures and course materials, including but not limited to exams, quizzes, study outlines, and similar materials are protected by copyright. These materials may not be shared, uploaded, distributed, reproduced, or publicly displayed without the express written permission of NAU. Sharing materials on websites such as Course Hero, Chegg, or related websites is considered copyright infringement subject to United States Copyright Law and a violation of NAU Student Code of Conduct. For additional information on ABOR policies relating to course materials, please refer to ABOR Policy 6-908 A(2)(5).

COURSE TIME COMMITMENT
Pursuant to Arizona Board of Regents guidance (ABOR Policy 2-224, *Academic Credit*), each unit of credit requires a minimum of 45 hours of work by students, including but not limited to, class time, preparation, homework, and studying. For example, for a 3-credit course a student should expect to work at least 8.5 hours each week in a 16-week session and a minimum of 33 hours per week for a 3-credit course in a 4-week session.

DISRUPTIVE BEHAVIOR
Membership in NAU's academic community entails a special obligation to maintain class environments that are conductive to learning, whether instruction is taking place in the classroom, a laboratory or clinical setting, during course-related fieldwork, or online. Students have the obligation to engage in the educational process in a manner that does not interfere with normal class activities or violate the rights of others. Instructors have the authority and responsibility to address disruptive behavior that interferes with student learning, which can include the involuntary withdrawal of a student from a course with a grade of "W". For additional information, see NAU's *Disruptive Behavior in an Instructional Setting* policy at https://nau.edu/university-policy-library/disruptive-behavior.

NONDISCRIMINATION AND ANTI-HARASSMENT
NAU prohibits discrimination and harassment based on sex, gender, gender identity, race, color, age, national origin, religion, sexual orientation, disability, veteran status and genetic information. Certain consensual amorous or sexual relationships between faculty and students are also prohibited as set forth in the *Consensual Romantic and Sexual Relationships* policy. The Equity and Access Office (EAO) responds to complaints regarding discrimination and harassment that fall under NAU's *Nondiscrimination and Anti- Harassment* policy. EAO also

assists with religious accommodations. For additional information about nondiscrimination or anti-harassment or to file a complaint, contact EAO located in Old Main (building 10), Room 113, PO Box 4083, Flagstaff, AZ 86011, or by phone at 928-523-3312 (TTY: 928-523-1006), fax at 928-523-9977, email at equityandaccess@nau.edu, or visit the EAO website at https://nau.edu/equity-and-access.

TITLE IX

Title IX of the Education Amendments of 1972, as amended, protects individuals from discrimination based on sex in any educational program or activity operated by recipients of federal financial assistance. In accordance with Title IX, Northern Arizona University prohibits discrimination based on sex or gender in all its programs or activities. Sex discrimination includes sexual harassment, sexual assault, relationship violence, and stalking. NAU does not discriminate on the basis of sex in the education programs or activities that it operates, including in admission and employment. NAU is committed to providing an environment free from discrimination based on sex or gender and provides a number of supportive measures that assist students, faculty, and staff.

One may direct inquiries concerning the application of Title IX to either or both the Title IX Coordinator or the U.S. Department of Education, Assistant Secretary, Office of Civil Rights. You may contact the Title IX Coordinator in the Office for the Resolution of Sexual Misconduct by phone at 928-523-5434, by fax at 928-523-0640, or by email at titleix@nau.edu. In furtherance of its Title IX obligations, NAU promptly will investigate or equitably resolve all reports of sex or gender-based discrimination, harassment, or sexual misconduct and will eliminate any hostile environment as defined by law. The Office for the Resolution of Sexual Misconduct (ORSM): Title IX Institutional Compliance, Prevention & Response addresses matters that fall under the university's Sexual Misconduct policy. Additional important information and related resources, including how to request immediate help or confidential support following an act of sexual violence, is available at https://in.nau.edu/title-ix.

ACCESSIBILITY

Professional disability specialists are available at Disability Resources to facilitate a range of academic support services and accommodations for students with disabilities. If you have a documented disability, you can request assistance by contacting Disability Resources at 928-523-8773 (voice), ,928-523-8747 (fax), or dr@nau.edu (e-mail). Once eligibility has been determined, students register with Disability Resources every semester to activate their approved accommodations. Although a student may request an accommodation at any time, it is best to initiate the application process at least four weeks before a student wishes to receive an accommodation. Students may begin the accommodation process by submitting a self-identification form online at https://nau.edu/disability-resources/student-eligibility-process or by contacting Disability Resources. The Director of Disability Resources, Jamie Axelrod, serves as NAU's Americans with Disabilities Act Coordinator and Section 504 Compliance Officer. He can be reached at jamie.axelrod@nau.edu.

RESPONSIBLE CONDUCT OF RESEARCH

Students who engage in research at NAU must receive appropriate Responsible Conduct of Research (RCR) training. This instruction is designed to help ensure proper awareness and application of well-established professional norms and ethical principles related to the performance of all scientific research activities. More information regarding RCR training is available at https://nau.edu/research/compliance/research-integrity.

MISCONDUCT IN RESEARCH

As noted, NAU expects every student to firmly adhere to a strong code of academic integrity in all their scholarly pursuits. This includes avoiding fabrication, falsification, or plagiarism when conducting research or reporting research results. Engaging in research misconduct may result in serious disciplinary consequences. Students must also report any suspected or actual instances of research misconduct of which they become aware. Allegations of research misconduct should be reported to your instructor or the University's Research Integrity Officer, Dr. David Faguy, who can be reached at david.faguy@nau.edu or 928-523-6117. More information about misconduct in research is available at https://nau.edu/university-policy-library/misconduct-in-research.

SENSITIVE COURSE MATERIALS

University education aims to expand student understanding and awareness. Thus, it necessarily involves engagement with a wide range of information, ideas, and creative representations. In their college studies, students can expect to encounter and to critically appraise materials that may differ from and perhaps challenge familiar understandings, ideas, and beliefs. Students are encouraged to discuss these matters with faculty.

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