ADVANCED REMOTE SENSING (GEOG 473/582)

New Mexico State University
Department of Geography

SPRING 2017
Lecture: Tue, 17:30-20:00; Breland Hall 192
Lab: Thu, 17:30-20:00; Breland Hall 192

Professor: **Dr. Michaela Buenemann**
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✉ elabuen@nmsu.edu
Office Hours: Tue, 10:15-12:00 and 13:30-15:30; Wed, 10:00-12:00 and 13:00-16:00; Thu, 10:15-10:45 and 14:30-15:15. Sign up on Dr. B.'s door to ensure her time is all yours! If the 10 office hours she is offering conflict with your schedule, please contact her to make an appointment.

T.A.: **Manuel Lopez**
Office: Breland Hall #142; ✉ mlopez72@nmsu.edu; ☎ (575) 646-3307
Advising Hours: Mon & Tue, 14:00-15:30; by appointment.

COURSE DESCRIPTION

Building on the fundamental remote sensing concepts, techniques, and applications introduced in the Introduction to Remote Sensing (GEOG 373/573), this course aims at familiarizing you with advanced topics in digital remote sensing applications, image evaluation, preprocessing, analysis, interpretation, and visualization. Specific topics include, but are not limited to, geometric and radiometric correction, image enhancement, image classification, change detection, and accuracy assessment. The course includes a lecture and lab component, both of which are student-centered and thus highly interactive.

STUDENT LEARNING OUTCOMES

Upon completion of this course, you should be able to:

1. explain basic and advanced remote sensing concepts and methods;
2. acquire, evaluate, and preprocess raw remote sensing images;
3. produce a series of image-derived indices and transformations;
4. calibrate and evaluate various remote sensing image classifications; and
5. perform digital change detection of remotely sensed data.

In addition, those of you that are graduate students should be able to critique a professional journal article and write a scientific research paper.

COURSE STRUCTURE

This is a **fast-paced course with a steep learning curve:** the course introduces a variety of interrelated advanced remote sensing concepts and methods. The major topics are treated somewhat separately in each of the chapters in your textbook as well as during the lectures and labs. However, the power of remote sensing can only be fully appreciated and exploited by synthesis and integration of the many topics discussed throughout the semester. An understanding of topics treated during the third week of class demands an understanding of the topics treated during the first and second weeks of class, and so forth. Similarly, remote sensing studies typically involve a series of interlinked processing steps, beginning with those discussed during the first few weeks of the semester and concluding with those discussed during the last few weeks of the semester. It is thus crucial that you always keep up with the readings, discussions, and assignments. **WE** will do our very best to **FACILITATE LEARNING** (i.e., to help you achieve the learning outcomes stated above)—we will always prepare and present class materials to the best of our abilities and give you tasks that will help you better learn key concepts and techniques. **YOU** are **RESPONSIBLE** for **LEARNING ITSELF**.

COURSE MATERIALS

Website: Course materials (e.g., lectures, labs, grades) can be found at https://learn.nmsu.edu/. To access course materials, simply log in to your Canvas account and click the link for this course. The website is a key element of this course and you are required to review its contents regularly. If you encounter problems related to the website, please contact us immediately.

E-mail: Official NMSU communication to you will come through your NMSU e-mail account. Access your NMSU e-mail frequently, or forward it to your current use address, as your success in college may ride on your ability to respond quickly. To guarantee a response to your emails, always a) begin your emails with a proper greeting that includes the name of the person/s you are emailing; b) conclude with a closing that includes your name; and c) use proper spelling, grammar, and punctuation. Unless we are away from the office with limited access to email, we will respond to your emails within one business day. Similarly, we expect you to respond to our emails in a timely manner.

Required Readings: You need to acquire a textbook for this course and have three options concerning the book itself: you buy/rent 1) the required text (**Jensen, J. R. 2016. Introductory Digital Image Processing. 4th edition. Glenview, IL: Pearson**), 2) an earlier edition of the text, or 3) any advanced remote sensing book of your own choice. If you choose a book other than the required book, you are responsible for correlating the content of your chosen book with the required reading assignments. Note that you may be able to check out the book from a library and that you may be able to purchase the book for discounted prices at used bookstores, thrift stores, or online at amazon.com, barnesandnoble.com, or textbookland.com. In addition to this textbook, we expect you to prepare some journal articles (available via Canvas) for class discussions later in the semester. Optional readings include and are not limited to the required book for GEOG 373/573 (Jensen, J. R. 2006. *Remote Sensing of the Environment: An Earth Resource Perspective*. 2/E ed. Upper Saddle River, NJ: Prentice-Hall).

Lab Manual: There is no formal lab manual for this class. All lab assignments will be made available for you on Canvas and Mapper.

Remote Sensing Software: We will use ENVI software for all image processing in the lab component of the course. ENVI is available on all computers in the geography lab room. In addition, to give you maximum flexibility in completing the labs, we will provide you with instructions for using ENVI on your personal computers.

GRADING

Your final course grade is determined by the points you accrue out of a possible 1000 points:

Exams (× 4):	240 points	24%	**1,000 Points (100%)**
Labs (× 12):	360 points	36%	
MCPs (× 10):	50 points	5%	
iRATs (× 10):	100 points	10%	
tRATs (× 10):	200 points	20%	
In-Class Activities (× 10):	50 points	5%	

Graduate Students: Upon completion of this course, the number of points listed above for undergraduate students will be adjusted to account for only 80 % of your final grade. You will earn the remaining 20% of your final grade through completion of additional projects.

Your final course letter grade will be based on the following scale:

A (4.0)	95-100%	**B (3.0)**	84-86%	**C (2.0)**	74-76%	**D (1.0)**	64-66%
A- (3.7)	90-94%	**B- (2.7)**	80-83%	**C- (2.0)**	70-73%	**D- (1.0)**	60-63%
B+ (3.3)	87-89%	**C+ (2.3)**	77-79%	**D+ (1.0)**	67-69%	**F (0)**	< 60%

Individual assignments and tests will not be curved (↑ or ↓). We *may* make adjustments of the final letter grade after an assessment of the class curve at the end of the term. We consider class participation, attendance, and improvement over the term as justification for discounting a grade that is uncharacteristically lower than others.

An **I (Incomplete)** grade will be assigned only if you are unable to complete the course due to circumstances beyond your control (e.g., documented illness or documented death or crisis in your immediate family) that develop after the last day to withdraw from the course. Job-related circumstances are generally not appropriate grounds for assigning an I. An I grade will not be used to avoid assigning of D, F, U, or RR grades for marginal or failing work.

Exams: There will be four exams. Exams 1, 2, 3, and 4 will account for 5% (50 points), 4% (40 points), 5% (50 points), and 10% (100 points) of your final course grade, respectively, and thus for a combined total of **24%** (240 points) of your final course grade. Each exam will be cumulative, assessing your learning since the beginning of the semester. All other exams will be written on paper and in class on the exam days indicated in the Tentative Course Outline below. All exams will be individual efforts. **Make-up exams:** If you have a legitimate excuse for a university-sanctioned activity or work-related event that will cause you to miss an exam, contact us prior to the official exam time so that we can schedule a make-up exam, and provide us with written documentation prior to or on the day of your make-up exam. If you have to miss an exam due to illness, contact us as soon as possible so that we can schedule a make-up exam, and provide us with written documentation on the day of the exam. If you fail to follow these guidelines or if you miss an exam for other reasons, you will receive 0 points for the exam.

Labs: There will be twelve lab exercises, each accounting for 3% (30 points) of your final grade or for a combined total of **36%** (360 points). The labs will thus be crucial to your overall success in this course. The labs are designed to help you learn how to apply concepts and techniques introduced in class. Each lab builds on the previous lab/s; it is thus critical that you complete all lab exercises. There are deadlines for the submission of project reports etc. in the

real world. To reinforce this and to teach you to work under these restrictions, late submissions will be given a score of 0 points. Exercises are to be turned in via Canvas not later than the beginning of your lab two weeks after they were assigned. This means you should allow extra time for glitches in computer hardware and software. Should you be unable to submit your work on time, submit it nonetheless and as soon as possible after the deadline: you will learn from completing the lab and you will receive valuable feedback for your work. If you are unable to submit your work on time due to extenuating circumstances, contact us as soon as possible: we will work with you to help you succeed! We invite you to collaborate with others to solve lab problems, but your lab submissions must clearly be your own work.

Muddy & Clear Points (MCPs): MCPs are written notes summarizing aspects of the readings that were unclear and aspects of the readings that made perfect sense to you. There will be ten MCPs this semester, each accounting for 0.5% (5 points) of your final grade. Collectively, the MCPs will thus determine **5%** (50 points) of your final course grade. MCPs are credit opportunities for you to reflect on your understanding of the class materials. They should serve as another incentive for you to prepare the readings for class. At the same time, they allow us to tailor each class meeting specifically to your needs, with emphasis on muddy points and no or only short discussions of clear points. MCPs must be completed individually and turned in via Canvas by the beginning of class on the days indicated in the Tentative Course Outline below.

Readiness Assessment Tests (**RATs):** Many **Learning Outcomes** (**LOs**; i.e., descriptions of things you should be able to do) could be formulated for each lecture, but some are particularly crucial to help you acquire the five overall LOs of this course (p. 1). To help you stay focused on the important issues, we will provide you with a set of "crucial LOs" (i.e., **study guide**) for all major topics and assess the degree to which you have acquired these LOs in the form of both **individual RATs (iRATs)** and **team RATs (tRATs)**. iRATs must be completed individually and turned in via Canvas by the beginning of class on the days indicated in the Tentative Course Outline below; tRATs will be completed by teams in class and are to be submitted via email to Dr. B. upon completion. As indicated in the Tentative Course Outline below, the RATs initially cover new material, i.e., material you are asked to prepare for class and thus material we don't expect you to fully understand right away. The reason for giving you these early RATs is twofold: they give you an incentive for preparing for class and us an idea of what you do or do not understand and, hence, what we should focus on in the lectures. Once we have received your initial iRATs and tRATs, we will provide you with feedback for improving the tRATs and invite you (not require you) to revise and resubmit them (tRATs only, not iRATs) for a potentially higher grade. There will be ten iRATs, each accounting for 1% (10 points) of your final course grade or for a combined total of **10%** (100 points), as well as ten tRATs, each accounting for 2% (20 points) of your final course grade or for a combined total of **20%** (200 points).

In-Class Activities: In-class participation is crucial for you to learn, and we will provide you with many in-class opportunities to do just that. By actively participating in these opportunities, you may earn 50 points (**5%**) of your final course grade. All in-class tasks will be completed in teams in class and are to be submitted via email to Dr. B. upon completion.

Teams & Peer Evaluations: Collaboration is an important component of most jobs and tends to be very rewarding. We thus encourage collaboration throughout the semester. To facilitate the process, you will be divided into teams, each comprised of about four students. Each team will be made up of a diversity of individuals, but different teams will be comparable to each other (e.g., each team will be composed of roughly the same number of geography and non-geography

majors). Members of every individual team will complete tRATs and In-Class Activities as just that—a team. However, while each team member will initially receive the same grades as all other team members, adjustments of each team member's grades (upward or downward) will be made based on peer evaluations that assess an individual's contribution to the success of the team (e.g., preparedness, reliability, participation in discussions, ability to compromise). It is thus in your own best interest to always be prepared and contribute as much as possible to teamwork and discussions.

Grades & Written Appeals: If you have any issues with a graded test, exam, lab, etc. (e.g., you feel a task was ambiguous and thus impossible to answer correctly or you feel your answer was correct and not ours), you and/or your team may prepare a written appeal and submit it to us. If we feel that your appeal has merit, you will be given credit accordingly.

Additional Requirements for Grad Students: If you are a graduate student, you are required to critique one professional journal article and compile your lab work as a scientific research paper.

Further details regarding each of the above grade components will be provided to you in class, lab, and/or on the course website.

POLICIES, CODES, ETC.

Students with Disabilities. Section 504 of the Rehabilitation Act of 1973 and the Americans with Disabilities Act Amendments Act (ADAAA) covers issues relating to disability and accommodations. If you have questions or need an accommodation in the classroom (all medical information is treated confidentially), contact: Trudy Luken, Director; Student Accessibility Services (SAS) - Corbett Center, Rm. 208; Phone: (575) 646-6840 E-mail: sas@nmsu.edu; Website: http://sas.nmsu.edu/

Non-Discrimination. NMSU policy prohibits discrimination on the basis of age, ancestry, color, disability, gender identity, genetic information, national origin, race, religion, retaliation, serious medical condition, sex, sexual orientation, spousal affiliation, and protected veterans status. Furthermore, Title IX prohibits sex discrimination to include sexual misconduct: sexual violence (sexual assault, rape), sexual harassment and retaliation. For more information on discrimination issues, Title IX, Campus SaVE Act, NMSU Policy Chapter 3.25, NMSU's complaint process, or to file a complaint contact: Lauri Millot, Title IX Coordinator; Agustin Diaz, Title IX Deputy Coordinator; Office of Institutional Equity (OIE) - O'Loughlin House, 1130 University Avenue; Phone: (575) 646-3635 E-mail: equity@nmsu.edu; Website: http://www.nmsu.edu/~eeo/

Other NMSU Resources. NMSU Police Department: (575) 646-3311, www.nmsupolice.com; NMSU Police Victim Services: (575) 646-3424; NMSU Counseling Center: (575) 646-2731; NMSU Dean of Students: (575) 646-1722; For Any On-Campus Emergencies: 911

Code of Academic Integrity. Enrollment in this course and acceptance of this syllabus is your **contract** constituting acceptance of all University policies regarding academic integrity, including but not limited to cheating and plagiarism. You are expected to comply fully with the NMSU Honor Code as presented in the Student Handbook (http://studenthandbook.nmsu.edu/). Students who are judged to be guilty of academic dishonesty (http://studenthandbook.nmsu.edu/student-code-of-conduct/academic-misconduct/) on any graded class component will receive no

points for that component, and we reserve the right to consider more severe penalties such as failure of the course and referral to the Dean and Student Judicial Affairs.

Absence Policy. Absences due to University-sanctioned activities, work-related events, holidays or special events observed by organized religions, or illness will be excused, if you provide us with official written documentation explaining your absence. We don't really have any additional absence policies. Just keep the following in mind: learning is your responsibility and, if you miss a lecture or lab, you will have to figure out how to "make it up;" your peers will evaluate you in terms of your contributions to the success of your team and the class and these evaluations will be used to convert team grades to individual grades.

Withdrawal. Withdrawal from this course is solely your responsibility; we will not drop you from this class under any circumstances. If you no longer wish to be enrolled in this course, you must withdraw from it. If you are still on the class roll at the end of the semester, you will receive a grade based on the work submitted.

What you can expect from us. We will be available in class, during office hours and scheduled appointments, and via email to respond to any questions or concerns you may have**.** Don't be shy and contact us as soon as ambiguities, problems, or concerns arise! We will take all of your concerns seriously and respond to you as soon and as specific as possible. We will address any issues that are of importance to all students in class and on Canvas. We will do our very best to always be prepared for class, grade assignments fairly, and return your work promptly (within one week). We reserve the right to change scheduled lectures, exams, and assignments. Any changes made will not adversely affect your workload or grade.

What we expect from you: Enrollment in this course and acceptance of this syllabus is your **contract** constituting acceptance of ALL New Mexico State University policies and codes as well as ALL specific policies outlined in this syllabus. We expect you to be on time for all class-related activities, submit all tasks as instructed, and always show "good" behavior toward both your instructor and peers. **HAVE FUN**!

TENTATIVE COURSE OUTLINE

Week	Date	Topic	Due: At Home | In Class * Pages in Jensen 2016
PART I: IMAGE PREPROCESSING & ENHANCEMENT			
1	01/24	**Welcome & Ice Breakers** Introductions, Teams, Etc. **Fundamentals of Remote Sensing (1)** Remote Sensing Definition Remote Sensing Process	✓ Study Syllabus & Get Textbook
	Lab	***No Lab***	
2	01/31	**Fundamentals of Remote Sensing (1)** Resolution Considerations Remote Sensing Systems Visual Image Interpretation Elements Electromagnetic Radiation Principles	✓ Reading #1: 1-32, 37-108, 185-204 (Materials from RS Intro Course)* ✓ MCP #1 & iRAT #1 (Topic 1) ✓ tRAT #1 (Topic 1)

		Color on Remotely Sensed Imagery	
	Lab	***Lab #1: Image Acquisition and Import***	
3	02/07	**Data Visualization & Evaluation (2)** Hardware and Software Data Visualization Histograms & Statistics	✓ Reading #2: 111-130, 131-151, 153-181* ✓ MCP #2 & iRAT #2 (Topic 2) ✓ tRAT #2 (Topic 2) ✓ Revision of tRAT #1
	Lab	***Lab #2: Data Viz and Evaluation***	
4	02/14	**Radiometric Correction (3)** Correction of Systematic Errors Atmospheric Correction Topographic Correction Peer Evaluation #1	✓ Reading #3: 205-232* ✓ MCP #3 & iRAT #3 (Topic 3) ✓ tRAT #3 (Topic 3) ✓ Revision of tRAT #2
	Lab	***Lab #3: Radiometric Correction***	✓ Lab #1
5	02/21	**Geometric Correction (4)** Geometric Errors Spatial Interpolation Intensity Interpolation	✓ Reading #4: 235-271* ✓ MCP #4 & iRAT #4 (Topic 4) ✓ tRAT #4 (Topic 4) ✓ Revision of tRAT#3
	Lab	***Lab #4: Geometric Correction***	✓ Lab #2
6	02/28	**Exam #1 (Topics 1-4)** **Image Derivatives (5)** Spatial Profiles Spectral Profiles Contrast Enhancements	✓ Prepare for Exam #1
	Lab	***Lab #5: Image Derivatives I***	✓ Lab #3
7	03/07	**Image Derivatives (5)** Spatial Filtering Texture Transformations Band Ratioing	✓ Reading #5: 273-353* ✓ MCP #5 & iRAT #5 (Topic 5) ✓ tRAT #5 (Topic 5) ✓ Revision of tRAT#4
	Lab	***Lab #6: Image Derivatives II***	✓ Lab #4
8	03/14	**Image Derivatives (5)** Principal Components Analysis Vegetation Indices Landscape Ecology Metrics Peer Evaluation #2	
	Lab	***Lab #7: Image Derivatives III***	✓ Lab #5
9	---	*Spring Break (03/20-03/24): No Lectures, No Labs*	
PART II: IMAGE CLASSIFICATION & CHANGE DETECTION			
10	03/28	**Exam #2 (Topics 1-5)** **Thematic Information Extraction: Introduction (6)** Introduction to Image Classification	✓ Prepare for Exam #2 ✓ Reading #6: 361-393, 557-580* ✓ MCP #6 & iRAT #6 (Topic 6) ✓ tRAT #6 (Topic 6)

		Feature Selection Calibration of Classification Models Evaluation of Classification Models	✓ Revision of tRAT#5
	Lab	***Lab #8: Classification Scheme & Reference Data Collection***	✓ Lab #6
11	04/04	**Information Extraction using Traditional Classifiers (7)** Traditional Unsupervised Classifiers Traditional Supervised Classifiers Object-Based Image Analysis	✓ Reading #7: 393-423* ✓ MCP #7 & iRAT #7 (Topic 7) ✓ tRAT #7 (Topic 7) ✓ Revision of tRAT #6 ✓ Grad Students: Article Critique
	Lab	***Lab #9: Classification using Traditional Unsupervised Classifiers***	✓ Lab #7
12	04/11	**Information Extraction using Artificial Intelligence (8)** Decision Trees & Regression Trees Support Vector Machines Neural Networks	✓ Reading #8: 430-453* & TBA ✓ MCP #8 & iRAT #8 (Topic 8) ✓ tRAT #8 (Topic 8) ✓ Revision of tRAT #7
	Lab	***Lab #10: Classification using Traditional Supervised Classifiers***	✓ Lab #8
13	04/18	Peer Evaluation #3 **Exam #3 (Topics 1-8)**	✓ Prepare for Exam #3
	Lab	***Lab #11: Classification using Machine-Learning Algorithms***	✓ Lab #9
14	04/25	**Change Detection (9)** Change Detection Considerations Change Detection Steps Change Detection Algorithms	✓ Reading #9: 501-551* ✓ MCP #9 & iRAT #9 (Topic 9) ✓ tRAT #9 (Topic 9) ✓ Revision of tRAT #8
	Lab	***Lab #12: Change Detection***	✓ Lab #10
15	05/02	**Remote Sensing Models and Advanced Image Analysis (10)** Remote Sensing Models Hyperspectral Data Collection Hyperspectral Data Analysis	✓ Reading #10: 459-496* & Strahler, Woodcock, and Smith 1986 ✓ MCP #10 & iRAT #10 (Topic 10) ✓ tRAT #10 (Topic 10) ✓ Revision of tRAT #9
	Lab	***Lab: Wrapping Things Up***	✓ Lab #11
16	**05/09**	**Final Exam (All Topics): 18:00 – 20:00** Peer Evaluation #4	✓ Prepare for Final Exam ✓ Revision of tRAT #10 ✓ Grad Students: Research Paper ✓ Lab #12