From the Associate Dean, Undergraduate Studies

Academic Integrity: In order to maintain a culture of academic integrity, members of the University of Waterloo community are expected to promote honesty, trust, fairness, respect and responsibility. **www.uwaterloo.ca/academicintegrity/**

Students who are unsure what constitutes an academic offence are requested to visit the on-line tutorial at **http://www.lib.uwaterloo.ca/ait/**

Note for students with disabilities: The Office for Persons with Disabilities (OPD), located in Needles Hall, Room 1132, collaborates with all academic departments to arrange appropriate accommodations for students with disabilities without compromising the academic integrity of the curriculum. If you require academic accommodations to lessen the impact of your disability, please register with the OPD at the beginning of each academic term.

Religious Observances: Student needs to inform the instructor at the beginning of term if special accommodation needs to be made for religious observances that are not otherwise accounted for in the scheduling of classes and assignments.

Grievance: A student who believes that a decision affecting some aspect of his/her university life has been unfair or unreasonable may have grounds for initiating a grievance. Read Policy 70 - Student Petitions and Grievances, Section 4, **www.adm.uwaterloo.ca/infosec/Policies/policy70.htm**. When in doubt please contact your Undergraduate Advisor for details.

♦ **Discipline:** A student is expected to know what constitutes academic integrity, to avoid committing academic offence, and to take responsibility for his/her actions. A student who is unsure whether an action constitutes an offense, or who needs help in learning how to avoid offenses (e.g., plagiarism, cheating) or about "rules" for group work/collaboration should seek guidance from the course professor, academic advisor, or the Undergraduate Associate Dean. For information on categories of offences and types of penalties, students should refer to Policy 71, Student Discipline, **www.adm.uwaterloo.ca/infosec/Policies/policy71.htm**. For typical penalties, check Guidelines for Assessment of Penalties, **www.adm.uwaterloo.ca/infosec/guidelines/penaltyguidelines.htm**

Appeals: A decision made or penalty imposed under Policy 70 - Student Petitions and Grievances (other than a petition) or Policy 71 – (Student Discipline) may be appealed if there is a ground. A student who believes he/she has a ground for an appeal should refer to Policy 72 (Student Appeals) **www.adm.uwaterloo.ca/infosec/Policies/policy72.htm**

Turnitin: Plagiarism detection software (Turnitin) will be used to screen assignments in this course. This is being done to verify that use of all materials and sources in assignments is documented. Students will be given an option if they do not want to have their assignment screened by Turnitin. In the first week of the term, details will be provided about arrangements and alternatives for the use of Turnitin in this course. For further information on UW's Turnitin guidelines, see: **http://uwaterloo.ca/academic-integrity/home/guidelines-instructors**

Unclaimed assignments: Unclaimed assignments will be retained until one month after term grades become official in quest. After that time, they will be destroyed in compliance with UW's confidential shredding procedures (uwaterloo.ca/central-stores/confidential-shredding)

LEARN: Users can login to LEARN via:
http://uwaterloo.ca/learn-help
Use your WatIAM/Quest username and password. Documentation is available at:
http://watiam.uwaterloo.ca /

Associate Dean
Undergraduate Studies

1 September, 2013

GEOG-371 Advanced Remote Sensing Techniques (0.5 CU)
Course Outline Fall 2016 (version 7-09-2016)

Instructor	Aaron Thompson	a4thomps@uwaterloo.ca **Office Hours: Mondays, 11:30 - 1:30** **EV1-235**
Lectures	Room: AL 208	Monday Mornings 8:30 am – 10:20pm
Labs	Room: EV2 1002A Code: 5,4,3,1	Friday mornings (Sect. 101): 10:30am-12:20pm Tuesday afternoons (Sect. 102): 2:30-4:20pm Friday afternoons (Sect. 103): 4:30-6:20pm Tuesday afternoons (Sect. 104): 4:30-6:20pm
Teaching Assistant	Vicky Vanthoff vrvantho@uwaterloo.ca Zishan Qiu Z24qiu@uwaterloo.ca	Office Hours: TBA Office Hours: TBA
MAD Assistant	Mike Lackner mlackner@uwaterloo.ca	By Appointment Only

Overview
Remote sensing is an important technique for environmental monitoring and scientific analysis. Remote sensing is used for global change studies (e.g. environmental change) and for more local scale applications such as urban landscape mapping, precision farming and many other day-to-day activities. This course introduces and develops advanced remote sensing information extraction techniques that are increasingly used by municipalities, environmental consultancies, federal agencies and industry. It builds on the fundamentals of remote sensing science and Earth observation systems (e.g. optical and microwave systems) introduced in GEOG271. It focuses on current information extraction processes used by government and non-government organizations and by professional Earth and Environmental system science researchers to provide information about human and physical environments.

Course Description
This course focuses on the use of remote sensing to map key environmental states. Emphasis is placed on the application of remote sensing methods and data processing for analysis of physical and human environments. The course presents advanced multispectral and high resolution techniques for further remote sensing and Earth observation work and gives the student a strong basis from which to develop their analytical skills.

Course Learning Goals:
- Build upon material introduced in GEOG 271 and GEOG 165/181.
- Deepen student understanding of the physical principles underlying remote sensing system measurements.
- Develop expertise in applying appropriate image processing and data modeling techniques for selected applications (land cover classification, urban form mapping, Earth system mapping).
- Be able to understand the uncertainties throughout the information extraction process.

- Develop an awareness of current remote sensing themes through directed readings.
- Understand how a remote sensing product can be integrated in a GIS project framework.
- Gain and develop a strong working knowledge of standard image processing software for remote sensing applications.

Learning Outcomes
At the end of the course, students will have a stronger understanding of the remote sensing approach to monitoring and mapping the Earth surface. Students will understand and be able to apply judiciously a range of information extraction methods and be able to quantify the error and uncertainty in the methods used. Students will also be ready to undertake GEOG471, the Remote Sensing Project.

Pre-requisite knowledge
It is essential that you can recall your knowledge from GEOG165/GEOG181 and GEOG271 as these courses form the foundations for GEOG371.

Weekly lectures and conduct
Each week, a lecture will be delivered that presents new material to students. Where appropriate you will be encouraged to participate in what should be a supportive learning environment. You may use a laptop or device to make notes *only*. Otherwise, laptops and devices must be shut down during the course of the lecture. Use of a device or laptop for purposes other than note taking may result in you being asked to leave the lecture hall.

Weekly Labs
- Access to the Geddes computer lab is restricted by code to those enrolled in particular courses including this one. Food and/or drink are NOT permitted in the Geddes lab (EV2-1002A).
- *Students are responsible for maintaining their own backups of their work.* There are a number of options available for backing up your work, including the network drive for ENV students. It is suggested that you keep two copies of your work in separate locations. Remember that you are only as far ahead as your latest backup!

Student Evaluation and Progress

Graded lab assignments (6 labs)	80%
Mid-term test	20%
Total	**100%**

- There are **six lab assignments to be submitted** that will form the final lab grade. Each assignment builds on the exercises in the previous 2-3 weeks. The shading in the course outline below indicates the substantive components of each lab.
- *Each lab assignment is to be completed and handed in hardcopy form at the start of their lab in the following week. Students must also submit their digital copy via the drop box on LEARN*. It will be graded and returned to the student within two weeks of submission. Late student submissions will take longer to grade and return.
- A cover sheet must be completed with all assignment hardcopy submissions (see below for the format).
- **Assignment sanctions**. It is in your interest to keep to the deadlines for assignment submission. Late work will be sanctioned with 10% deducted from the assignment for

each week or part thereof for which the work is late. Sanctioned work will receive no feedback. Authorized medical notes, or requests that have been granted by the instructor ***prior to the deadline*** are the only valid way of obtaining an extension.

- An unseen written mid-term test is set for 31 October *in class* and accounts for the remaining 20% of the course. Students will choose to answer two essay questions out of five in 1.5 hours. Questions will be based on material and readings covered in the first five weeks of the course.

Students are **required** to attend a five-minute meeting with the instructor in the third and fourth weeks of the course to discuss progress and any issues that might have arisen. Office hours or lab times can be used for this purpose. Any more in-depth issues may be dealt with through an appointment with the TAs or the instructor.

Academic Integrity
Please make sure that you are familiar with what constitutes academic integrity from the University's excellent web site http://www.lib.uwaterloo.ca/ait/. You should familiarize yourself with this web site. Sanctions will be applied to submitted work where the rules are not followed.

University of Waterloo LEARN Course Environment:
This course uses the LEARN course environment for course material dissemination and information exchange. It will also be used for submitting coursework. LEARN is a web-based course management system that enables instructors to manage course materials (posting of lecture notes etc.), interact with their students (drop boxes for student submissions, on-line quizzes, discussion boards, course e-mail etc.), and provide feedback (grades, assignment comments etc.). YOU NEED TO ENSURE YOU CAN ACCESS LEARN.

Logging Into LEARN
Since LEARN is a web-based system, you will need a browser. Once you have started up your browser, type in the following URL: http://uwaterloo.ca/learn-help Please note that announcements regarding LEARN (service outages etc.) are posted; it is a good idea to check these regularly.

Getting Help
A LEARN student guide can be found at **http://uwaterloo.ca/learn-help**.

Course Readings
Recommended Text:
Jensen, J.R., 2015. *Introductory Digital Image Processing: A Remote Sensing Perspective*. Fourth Edition. Prentice Hall, Toronto, Canada, 623pp. Hardcopy is available in the book shop.

- Online version is available for purchase
- 2 copies available in library for 3-hour loan (G70.4 .J46 2005, G70.4 .J46 2016)
- Used?

Other Useful Remote Sensing Textbooks:
Campbell, J.B., 2011 *Introduction to Remote Sensing* (Fifth Edition), The Guilford Press, 626pp.
Jensen, J.A. 2007 *Remote Sensing of the Environment: An Earth Resource Perspective*, Second Edition, Prentice Hall, Toronto, Canada, 592pp

Continued…

Lillesand, T.M., R.W. Kiefer, and J.W. Chipman. 2004, *Remote Sensing and Image Interpretation* (Fifth Edition), John Wiley & Sons, Canada, 784pp.

Mather, P.M. 2004 *Computer Processing of Remotely-sensed Images*, (Third Edition). John Wiley & Sons Canada, 442pp.

Mather, P.M. and B. Tso. 2009 *Classification Methods for Remotely Sensed Data*, Second Edition, CRC Press 376pp.

Richards, J.A. 2013 Remote Sensing Digital Image Analysis: An Introduction (5th Edition). Springer. *Available Online through UW Library Service.*

This course deals with advanced remote sensing and digital information extraction methods. The recommended text (Jensen, 2015) covers many image processing aspects in the course with others covered by the other texts. For students planning to take GEOG 471, it is recommended that you obtain a copy of this text, as it will be a useful reference in this project course.

Lecture Outline

Week (date)	**Lecture**	**Lab (101,102,103,104)**	**Grade**
1 (12/9/2016)	RS Instrument characteristics and orbits: spatial and temporal resolution.	Introduction to ENVI: image contrast enhancement, spatial filters *13/9/2016 & 16/9/2016*	A1 (5%)
	Readings: Jensen (2015), Chapters 1 & 2. Dewitte, O., Jones, a., Elbelrhiti, H., Horion, S., & Montanarella, L. (2012). Satellite remote sensing for soil mapping in Africa: An overview. *Progress in Physical Geography*, *36*(4), 514–538. doi:10.1177/0309133312446981. Wang, K., Franklin, S. E., Guo, X., He, Y., & McDermid, G. J. (2009). Problems in remote sensing of landscapes and habitats. *Progress in Physical Geography*, *33*(6), 747–768. doi:10.1177/0309133309350121		
2 (19/9/2016)	Image quality, geometric and radiometric correction.	Analyzing image quality, re-projecting data, and radiometric correction *20/9/2016 & 23/9/2016*	A2 15%
	Readings: Jensen, (2015) Chapters 4 - 7 Smith, D.P. and S.F. Atkinson (2001) Accuracy of rectification using topographic map versus GPS ground control points. *Photogrammetric Engineering and Remote Sensing*, 67(5): 565-570. (TA593.A2 P5) Song, C., Woodcock, C., Seto, K., Lenney, M., & Macomber, S. (2001). Classification and change detection using Landsat TM data: when and how to correct atmospheric effects? *Remote sensing of Environment*, *75*(00), 230–244.		
3 (26/9/2016)	Image enhancements and image transformations	TC, PCA, pan-sharpening *27/9/2016 & 30/9/2016*	
	Readings: Jensen (2015) Chapters 5 & 8 Huete, A., Liu, H., Batchily, K., & van Leeuwen, W. (1997). A comparison of vegetation indices over a global set of TM images for EOS-MODIS. *Remote sensing of Environment, 59*, 440–451. Zhao, G. and Maclean, A.L. (2000) A comparison of canonical discriminant analysis and principal component analysis for spectral transformation, *Photogrammetric Engineering and Remote Sensing*, 66(7): 841-847. (TA593.A2 P5)		

Week (date)	Lecture	Lab (101,102,103,104)	Grade
4 (3/10/2016)	Lidar I Introduction to lidar RS	Lidar 1 – Airborne Lidar and Analysis *4/10/2016 & 7/10/2016*	
	Readings: Jensen (**2007**) Chapter 10. Lidar Remote Sensing		
12/10/2016	Thanksgiving – no lecture	No Labs	
5 (17/10/2016)	Lidar II Lidar data processing	Lidar 2 – Field Work and Airborne/Ground-based Integration *18/10/2016 & 21/10/2016*	
	Readings: Jensen (**2007**) Chapter 10. Lidar Remote Sensing Weltz, M., Ritchie, J., & Fox, H. (1994). Comparison of laser and field measurements of vegetation height and canopy cover. *Water Resources Research*, *30*(5), 1311–1319. St-Onge, B., & Jumelet, J. (2004). Measuring individual tree height using a combination of stereophotogrammetry and lidar. *Canadian Journal of Forest Research*, 34(10), 2122–2130. doi:10.1139/X04-093 Special Issue: Photogrammetric Engineering and Remote Sensing March 2011 (Vol 77, No. 3) Various papers on lidar RS for forest biomass. Hellesen, T., & Matikainen, L. (2013). An Object-Based Approach for Mapping Shrub and Tree Cover on Grassland Habitats by Use of LiDAR and CIR Orthoimages. *Remote Sensing*, *5*(2), 558–583. doi:10.3390/rs5020558		A3 15%
6 (24/10/2016)	Per pixel classification (Unsupervised [ISODATA] & supervised [MLC/SVM])	Lidar 3 – Field Work and Airborne/Ground-based Lidar Integration *25/10/2016 & 28/10/2016*	
	Readings: Jensen (2015) Chapter 9 Xie, Y., Sha, Z., & Yu, M. (2008). Remote sensing imagery in vegetation mapping: a review. *J. Plant Ecology* , *1:* 9–23. doi:10.1093/jpe/rtm005 Wu, W. and Shao, G. (2002) Optimal combinations of data, classifiers, and sampling methods for accurate characterizations of deforestation, *Canadian Journal of Remote Sensing*, 28(4): 593-600. (TR810 .C35x)		
7 (31/10/2016)	**MID-TERM (1.5 hour)** Accuracy Assessment	Classification (ISODATA + MLC/MH/SVM) *1/11/2016 & 4/11/2016*	
	Readings: Jensen (2015) Chapter 13 Congalton, R. (1991). A review of assessing the accuracy of classifications of remotely sensed data. *Remote Sensing of Environment*, 37: 35–46. Foody, G. M. (2002). Status of land cover classification accuracy assessment. *Remote Sensing of Environment*, *80*(1), 185–201. doi:10.1016/S0034-4257(01)00295-4		A4 15%
8 (7/11/2016)	Object-based image analysis (OBIA)	Accuracy assessment *8/11/2016 & 11/11/2016*	
	Readings: Jensen Chapter 13 Blaschke, T. (2010). Object based image analysis for remote sensing. *ISPRS Journal of Photogrammetry and Remote Sensing*, *65*(1), 2–16. doi:10.1016/j.isprsjprs.2009.06.004 Myint, S. W., Gober, P., Brazel, A., Grossman-Clarke, S., & Weng, Q. (2011). Per-pixel vs. object-based classification of urban land cover extraction using high spatial resolution imagery. *Remote Sensing of Environment*, *115*(5), 1145–1161. doi:10.1016/j.rse.2010.12.017		
9 (14/11/2016)	Hyperspectral information extraction.	OBIA eCognition example *15/11/2016 & 18/11/2016*	A5 15%
	Readings: Jensen (2015) Chapter 11 Adams *et al.* (2010) Multispectral and hyperspectral remote sensing for		

	identification and mapping of wetland vegetation: a review, *Wetlands Ecol and Management*, 18(3): 281-296. DOI: 10.1007/s11273-009-9169-z		
Week (date)	**Lecture**	**Lab (101,102,103,104)**	**Grade**
10 (21/11/2016)	Radar I Advanced radar systems: TSX, RSAT2, ALOS.	Fuzzy classifiers 22/11/2016 & 25/11/2016	A5 15%
11 (28/11/2016)	Radar II Radar application	Radar lab 1 & 2 *29/11/2016 & 2/12/2016*	A6 15%
	Readings: Jensen (2007) Chapter 9 Rosenqvist, A., & Shimada, M. (2007). ALOS PALSAR: A pathfinder mission for global-scale monitoring of the environment. *IEEE Transactions on Geoscience and Remote Sensing*, *45*(11), 3307–3316. Kovacs, J. M., Vandenberg, C. V., Wang, J. and F. Flores-Verdugo (2008) The use of multipolarized spaceborne SAR backscatter for monitoring the health of a degraded mangrove forest. *Journal of Coastal Research* 24: 248-254. (doi:10.2112/06-0660.1)		
12 (5/12/2016)	Roundup: change analysis	No Lab	
	Readings: TBD		

*(Shaded labs indicate the labs that contribute to the four **lab assignments**)*

PLEASE NOTE: The course instructor and TAs will respond to e-mail queries within 3 business days. ***Only University of Waterloo-derived email address requests will be answered.***

Assignment Checklist (To be completed and submitted with ALL assignments)

Please read the checklist below following the completion of your assignment. Once you have verified these points, hand in this signed checklist with your assignment.

1. I have referenced and footnoted all ideas, words or other intellectual property from other sources used in the completion of this assignment.

2. I have included a proper bibliography, which includes acknowledgement of all sources used to complete this assignment.

3. This assignment was completed by my own efforts and I did not collaborate with any other person for ideas or answers.

4. This is the first time I have submitted this assignment or essay (either partially or entirely) for academic evaluation.

Signed:_____ Date:_____
Print Name: _____ UW-ID# _____