Syllabus for GEOS 657 – Microwave Remote Sensing

1. Course Information:

- **Title:** Microwave Remote Sensing
- **Number:** GEOS 657
- **Credits:** 3
- **Prerequisites:** GEOS 422 or equivalent
- **Time:** Tuesdays (lectures), 2-4pm (AKST; UTC-9)
  Thursdays (labs), 2-4:45pm (AKST; UTC-9)
- **Course Type:** In-person and synchronous online:
  Fairbanks: CRN 37489; Other: CRN: 35293)

2. Instructor Information:

- **Name:** Franz J Meyer, Geophysical Institute, UAF
- **e-mail:** fjmeyer@alaska.edu
- **Phone:** 474-7767
- **Office:** WRRB 106D (office hours: ad-hoc/by appointment also via Google Hangout)

3. Course Material:

a. Textbooks:

Large parts of the class will follow a textbook published by Woodhouse (2006). This textbook is listed in the following list of reading materials as required (R) reading. In addition to this book, other supplemental (S) books are listed in the table, which provide good summaries of the material covered in the class.

- Woodhouse, I.H. (2006): Introduction to Microwave Remote Sensing. CRC Press, Taylor & Francis – (R).
- Meyer, F.J. (2018): Spaceborne Synthetic Aperture Radar – Principles, Data Access, and Basic Processing Techniques. SAR Handbook: Comprehensive Methodologies for Forest Monitoring and Biomass Estimation, NASA, pp.: 21-64
- Hanssen, R. (2001). Radar Interferometry: Data Interpretation and Error Analysis, Kluwer Academic Publishers – (S).
- Olivie, C. & Quegan, S. (2004): Understanding Synthetic Aperture Radar Images. Scitech – (S).
- Ferretti, A. (2014): Satellite InSAR Data – Reservoir Monitoring from Space. EAGE Publications – (S).

b. Journal Articles:

Original research articles from refereed journals will be assigned as reading to cover specific recent developments in microwave remote sensing and related disciplines. The articles will be made available through the class website, Blackboard, or similar means in due time.

c. Computer Software and Programming Work:

This class will rely exclusively on open-source software tools! Software solutions will include today's leading open-source community software packages such as the JPL-developed SAR

Scientific Computing Environment (ISCE), open-source python frameworks for source model inversion, and InSAR time series solutions such as MIntPy. All labs and materials are available through public GitHub repositories such as https://github.com/uafgeoteach/GEOS657_MRS.

For many of the more involved processing labs of this class, we will use OpenSARLab, a fully open-source cloud-based SAR data processing environment located in the Amazon Web Services (AWS) cloud. OpenSARLab was developed as part of NASA-funded research grants and is now maintained by the Alaska Satellite Facility. Using OpenSARLab has many advantages over physical computer pools. It comes pre-installed with all relevant processing tools to spare you the painful trouble of installing individual packages by hand. In OpenSARLab, all machines are identical. This ensures similar processing speed and identical software behavior for all participants. Finally, we ensure that all machines are correctly scaled, so that you can complete your assignments in a timely manner without ever running out of space. All lab exercises can be done from a student's personal computer, tablet, or other internet-enabled device.

4. Course Description:

This course will introduce the students to the principles and applications of microwave remote sensing. It includes the sensor technology, platforms and data portals to retrieve data. Principle processing techniques and applications of active and passive microwave remote sensing data will be covered. The laboratory part of the course will provide hands-on experience with the most relevant processing techniques and the possibility of using these techniques for a student-defined term project in areas of geology, seismology, volcanology, cryosphere, hydrology, environmental sciences, etc. Advanced processing techniques such as InSAR, or polarimetric SAR are included.

5. Course Goals and main Learning Outcomes:

The main goal of this course is to provide students with the background needed to use SAR and InSAR data as a source of physical and geodetic information. The course starts with an introduction to passive and active microwave remote sensing and a discussion of methods of Synthetic Aperture Radar (SAR) processing. It then presents an in-depth description of methods and applications of InSAR, including traditional InSAR methods and advanced InSAR Time Series analysis techniques. A thorough description of the main limitations and error sources of these techniques is included to allow for the retrieval of geodetic information from SAR and InSAR observations. It will be shown that SAR and InSAR data can be used to provide geodetic observations of geodynamic and anthropogenic processes of the earth's surface and interior with high accuracy and resolution. It will also be shown that SAR data can provide high resolution observations of atmospheric and ionospheric constituents. Toward the end of the semester, methods for the integration of geodetic observations from SAR with geophysical models and observations from other sensors will be presented.

6. Instructional Methods:

- Assignments and grades (along with general course information and handouts) will be posted on Blackboard: classes.alaska.edu.
- Lectures will be the primary mode of instruction. Some lectures will be supplemented with

computational examples to prepare students for homework problems.
- Each student is expected to lead one extended discussion of a case study where microwave remote sensing data is integrated in a geoscience problem.

7. Grading Criteria:

- Interim short test / quiz: 10%
- Homework assignments: 25%
- Reading & discussion contribution: 15%
- Independent project: 50% (25% presentation, 25% term paper)

8. Timeline and Content of the Class

Week	Lecture/Lab #	Date		Topic	Preparatory Readings	Assignment distributed
1:	Lecture 1 & 2	Jan	17	Introduction; History of Microwave Remote Sensing; some mathematical background		**Self-assessment exercise**
	Lecture 3		19	Properties and Propagation of EM Waves	Woodhouse 23-34	
2:	Lecture 4		24	Interaction of Microwaves with the Atmosphere; Interaction with discrete objects	Woodhouse 112 – 149	
	Lab 1		26	**LAB:** Analysis and interpretation of microwave images		**1**
3:	Lecture 5		31	How to Detect Microwaves; Antennas; Sensor Calibration	Woodhouse 151-165	
	Lecture 6	Feb	2	PASSIVE MICROWAVE SYSTEMS Atmospheric Sounding	Woodhouse 179-186; 200-202	
4:	Lecture 7		7	ACTIVE MICROWAVE SYSTEMS Principles of RADAR, Radar Altimetry, Scatterometry	Woodhouse 221-250	
	Lab 2		9	**LAB:** Ground-based radar demo		
5:	Lecture 8		14	IMAGING RADARS Real Aperture and SYNTHETIC APERTURE RADARS (SARs)	Woodhouse 259-270	
	Lecture 9		16	SYNTHETIC APERTURE RADAR (Geometric distortions; Speckle; Geocoding of SAR data)	Woodhouse 271-300	
6:	Lecture 10 & Lab 3		21	SAR Image Acquisition Modes; How to Access SAR Data **LAB:** SAR Image Processing and	SAR Handbook Chapters 2.1, 2.2, 2.5 & 2.6.1	**2**

				Geocoding		
	Lab 4		23	**LAB:** Time-Series Analysis of SAR images with Jupyter Notebooks		**3**
7:	Lecture 11		28	POLARIMETRIC SAR (POLSAR) (Concepts & Applications)		
	Lecture 12	Mar	2	RADAR INTERFEROMETRY (Concepts; Configurations)	Woodhouse 312-331	Project Topics Due
8:	Lecture 13		7	DIFFERENTIAL INSAR (d-InSAR) (Concepts; applications; limitations & error sources)	Woodhouse 336-340	
			9	**Term Project Concept Presentations**		
March 13 – 17: SPRING BREAK (no classes)						
9:	Lab 5		21	**LAB:** InSAR processing using topsApp in ISCE2	SAR Handbook Chapter 2.6.2	
			23	**MID TERM EXAM**		
10:	Lecture 14		28	Geophysical Modeling using InSAR		
	Lab 6		30	**LAB:** d-InSAR for Volcano Source Modeling		**4**
11:	Lecture 15	Apr	4	Interpreting Co-Seismic Interferograms		**5**
	Lab 7		6	**LAB:** d-InSAR-based Earthquake Modeling		
12:	Lecture 16		11	InSAR Time Series Analysis (Concepts; PSInSAR Methods)	Ferretti Chapter 4.1	
	Lab 8		13	**LAB:** Change Detection; Hydrology Mapping from time-series SAR		**6**
13:	Lecture 17		18	InSAR Time Series Analysis (The SBAS Approach; Comparison of SBAS and PSInSAR)	Ferretti Chapter 4.2	
	Lab 9		20	**LAB:** InSAR Time Series Analysis using MintPy		**7**
14:	Lab 10		25	**LAB**: End-to-End InSAR Time Series Processing		
			27	Open for Class Project Work		
15:		May	2	**Final Project Presentations and Project Writeup**		
			4	**Final Project Presentations and Project Writeup**		

9. Course Policies:

- Attendance: All students are expected to attend and participate in the offered lectures and labs. Online attendance is permissible.
- Participation and Preparation: Students are expected to come to class with assigned reading and other assignments completed as noted in the syllabus.
- Homework Assignments:
  - All assignments are due at the start of class on the due date noted in the Syllabus.
  - Late assignments will be accepted with a 5% penalty per day late.
  - Homework submission via email to fjmeyer@alaska.edu is encouraged.
  - The lowest homework assignment will be dropped when computing the course grade.

Homework Tips: Please type or write neatly, keep the solutions in the order assigned and bundle your answers in a single pdf file. Include only relevant computer output in your solutions (a good approach is to cut and paste the relevant output for each problem into an editor such as MS Word or Latex). Also clearly circle or highlight important numbers in the output, and label them with the question number. I also suggest that you to include computer code you may have used to derive your answers, both so that you can refer back to it for future assignments and so that I can identify where a mistake may have occurred. Display numerical answers with a reasonable number of significant figures and with units if the quantity is not dimensionless.

Homework scores are based on clarity of work, logical progression toward the solution, completeness of interpretation and summaries, and whether a correct solution was obtained. I encourage you to discuss homework problems with other students, however the work you turn in must be your own.

- Graded Assignments: Assignments will be graded for students within seven days of their receipt and returned at the end of the next class.
- Reporting Grades: All student grades, transcripts and tuition information are available on line at www.uaonline.alaska.edu.
- Consulting fellow students: Students are welcome to discuss with each other general strategies for particular homework problems (e.g., study groups are encouraged). However, write-ups handed in by a student—including any computer codes—must be individual work.
- Plagiarism: Students must acknowledge any sources of information—including fellow students—that influenced their homework assignments or final project. Any occurrence of plagiarism will result in a maximal penalty of forfeiture of all points for the particular homework assignment. If the plagiarism is between two students, then both students will potentially receive the penalty.

Furthermore, as a UAF student, you are subject to the student Code of Conduct. The university assumes that the integrity of each student and of the student body as a whole will be upheld. It is your responsibility to help maintain the integrity of the student community. For additional information, contact the Dean of Student Services or web http://www.alaska.edu/bor/regulation/9r/r09-02.html/. The UAF Honor Code (Student Code of Conduct) defines academic standards expected at the University of Alaska Fairbanks.

10. Term project:

A term project, to be completed by the end of the semester, will be aimed at applying skills and expertise acquired during the course to a specific scientific or engineering problem. Students are highly encouraged to define a project of their own (e.g., originating from thesis-related research), but a number of project suggestions (incl. data, samples etc.) will also be offered by the instructor.

11. Student Academic Support:

- Speaking Center (907-474-5470, uaf-speakingcenter@alaska.edu, Gruening 507)
- Writing Center (907-474-5314, uaf-writing-center@alaska.edu, Gruening 8th floor)
- UAF Math Services, uafmathstatlab@gmail.com, Chapman Bld (for math fee paying students only)
- Developmental Math Lab, Gruening 406
- The Debbie Moses Learning Center at CTC (907-455-2860, 604 Barnette St, Room 120, https://www.ctc.uaf.edu/student-services/student-success-center/)
- For more information and resources, please see the Academic Advising Resource List (https://www.uaf.edu/advising/lr/SKM_364e19011717281.pdf)

12. Student Resources:

- Disability Services (907-474-5655, uaf-disability-services@alaska.edu, Whitaker 208)
- Student Health & Counseling [**6 free counseling sessions**] (907-474-043, https://www.uaf.edu/chc/appointments.php, Whitaker 203)
- Ctr for Student Rights & Responsibilities (907-474-7317, uaf-studentrights@alaska.edu, Eielson 110)
- Associated Students of the University of Alaska Fairbanks (ASUAF) or ASUAF Student Government (907-474-7355, asuaf.office@alaska.edu, Wood Center 119)

13. Student Protection and Services Statement:

UAF embraces and grows a culture of respect, diversity, inclusion, and caring. Students at this university are protected against sexual harassment and discrimination (Title IX). Faculty members are designated as responsible employees which means they are required to report sexual misconduct. Graduate teaching assistants do not share the same reporting obligations. For more information on your rights as a student and the resources available to you to resolve problems, please go to the following site: https://catalog.uaf.edu/academicsregulations/students-rights-responsibilities/.

14. Disability Services Statement:

I will work with the Office of Disability Services to provide reasonable accommodation to students with disabilities.

15. COVID-19 Statement:

Students should keep up-to-date on the university's policies, practices, and mandates related to COVID-19 by regularly checking this website:
https://sites.google.com/alaska.edu/coronavirus/general-info

Further, students are expected to adhere to the university's policies, practices, and mandates and are subject to disciplinary actions if they do not comply.

16. Notice of Nondiscrimination:

The University of Alaska is an affirmative action/equal opportunity employer and educational institution. The University of Alaska does not discriminate on the basis of race, religion, color, national origin, citizenship, age, sex, physical or mental disability, status as a protected veteran, marital status, changes in marital status, pregnancy, childbirth or related medical conditions, parenthood, sexual orientation, gender identity, political affiliation or belief, genetic information, or other legally protected status. The University's commitment to nondiscrimination, including against sex discrimination, applies to students, employees, and applicants for admission and employment. Contact information, applicable laws, and complaint procedures are included on UA's statement of nondiscrimination available at www.alaska.edu/nondiscrimination. For more information, contact:

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