The University of Michigan
Department of Climate and Space

Climate 585 - Introduction to Remote Sensing and Inversion Theory

Fall Term 2021

Instructor:	Chris Ruf, 2527A Space Research Building, 734-764-6561, cruf@umich.edu
References:	F.T. Ulaby and D. Long, *Microwave Radar and Radiometric Remote Sensing*, Univ. of Michigan Press, ISBN 978-0-472-11935-6, 1016 pp, 2014. C.D. Rodgers, *Inverse Methods for Atmospheric Sounding*, World Scientific Publ., Singapore, ISBN: 981022740X, 240 pp, 2000. S. Twomey, *Introduction to the Mathematics of Inversion in Remote Sensing and Indirect Measurements*, Dover Publ., Mineola, NY, ISBN: 0486694518, 237 pp, 1997. (All references are on reserve for this course at the Duderstadt library)
Lecture:	Mon/Wed/Fri at 1:30-3:00 in Room 2422 Climate & Space Research Building
Office Hours:	Mon at 3:00-4:00 in Room 2527A Climate & Space Research Building

Course Overview

This course is intended to introduce the student to remote sensing methods. Physical processes and radiative transfer relationships are reviewed that relate geophysical parameters to remotely sensed measurements. The mathematical expression for these processes is referred to as the "forward model". A number of mathematical inversion methods are used in remote sensing to invert the forward model and solve for the geophysical parameters. These methods are developed and applied in this course. Some of the topics covered include the estimation of atmospheric profiles of temperature and constituent composition from satellite spectrometer measurements, the optimal design of spectrometers by maximizing the information content of the measurements, Bayesian and optimal estimation methods, and linear and non-linear methods of regression analysis. This course should be of interest to students who work with remotely sensed data – to gain a better understanding of the relationship between the raw radiance measurements and the estimated geophysical parameters. It is well suited to students with an interest in the application of inverse methods concepts to problems of current interest in remote sensing. The methods are also useful for students interested in the design of remote sensing instruments.

Prerequisite skills:

- Introductory radiative transfer or electromagnetics
- Intermediate linear algebra and random variables
- Intermediate scientific computer programming

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Course Outline

I. Introduction to remote sensing and the inverse problem (1 lecture)
Examples of remote sensing problems requiring inversion.

II. Review of linear vector spaces and component decomposition (3 lectures)
Vector spaces, linear operators, bases, determinants, eigenvalues and eigenvectors.

III. Review of linear function spaces and component decomposition (1 lecture)
Projections, orthogonal functions, skewness, covariance,

IV. Review of random variable and stochastic processes (3 lectures)
Descriptions of noise processes and propagation of noise through a linear system. Noise correlation and covariance.

V. Forward Model I – Atmospheric Structure and Radiative Transfer (2 lectures)

VI. Forward Model II – Surface emissivity and composite TB (3 lectures)

VII. Regression analysis (4 lectures)
Minimization of quadratic functionals, least squares solution, linear regression, multi-linear regression, skewed and orthogonal polynomial fits, Newton-Raphson non-linear regression, constrained least squares solutions.

VIII. Inversions with constrained smoothing (3 lectures)
Measures of smoothness, constrained inversion, and error propagation. Effects on skewness.

IX. Other inversion methods (4 lectures)
Statistical inversion, optimal estimation, Bayesian estimation

X. Information content and instrument design (3 lectures)
Statistical interdependence of measurements, benefits of over sampling, error magnification due to processing.

XI. Applications (distributed throughout the term) (10 lectures)

XII. Topical Problems of Interest (2 lectures)

XIII. Midterm & Review for Final Exam (2 lectures)

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Homework and Exam Policies

Homework

- Homework will be assigned every one to two weeks and will be due one week later.
- Homework should be handed in in class on the due date.
- Informal discussion of homework problems with classmates is encouraged. But solutions must be individually prepared.
- Late homework will not be accepted unless arrangements are made with the instructor beforehand.

Midterm and Final Exams

- Lecture notes, homework solutions and copies of assigned readings are permitted during the exams.
- A simple calculator is permitted, but not a laptop or on-line access.
- No additional books or reference materials are permitted.
- Midterm will be on 22 Oct 2021 in class
- Final Exam will be on 15 Dec 2021 at 1:30-3:30 pm

Grading Policy

60%	Homework
15%	Midterm Exam (covering material from lectures, assigned readings, and homework)
25%	Final Exam (comprehensive but focused on 2nd half of term)
100%	TOTAL