AT 652 -- Atmospheric Remote Sensing

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Fall 2024

Course Objective – To familiarize stuudents with the basic principles of satellite- and ground-based atmospheric remote sensing, to make them comfortable with today's broad spectrum of algorithms, and to provide a sense for where the logical progress will occur in the field.

Office hours: Any time the door is open or by appointment. Initiate with an e-mail.
Course material on Web site: http://rain.atmos.colostate.edu / Courses / AT652

Course Outline

1. **Introduction**
   - Course detail, objectives and outline
   - Satellite platforms and orbits
   - Inversion theory (brief overview)
2. **Basic properties of electromagnetic radiation**
   - Electromagnetic spectrum
   - Propagation, polarization and Doppler effect
   - Surface Properties across the EM spectrum
   - Extinction and Beer's law
3. **Interaction on the microscopic scale: molecular absorption**
   - Molecular absorption spectra
   - Line absorption, transmission functions
   - Radiative transfer
   - Column water vapor and liquid water
   - Weighting functions, sounding of temperature and moisture
4. **Interaction on the macroscopic level: particle scattering**
   - Refractive index, scattering
   - Particle scattering, backscattering: Depolarization ratios, ZDR and CDR
   - Radiative transfer
   - Radar and lidar remote sensing
5. **Optimal Estimation**
   - OE solutions
   - Bayes' theorem
   - Data Fusion
   - Artificial Intelligence/Machine Learning
   - Process Understanding
6. **Examples**
   - Precipitation
   - Carbon Dioxide

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Course Expectations:

Aside from attendance and interaction in regular lectures,

- A paper will be assigned most Thursdays (see schedule for paper). A student's name will be chosen randomly on the following Tuesday. Students should be prepared to present 2-3 minute summary (w/o slides) at that time. Notes are fine but reading of notes is discouraged.
- A group project detailing a specific "data fusion" project will be assigned on October 24th to assess student progress in the course.
- A final project will be assigned Nov. 12th to gauge student's ability to apply material learned in the course to build a working retrieval algorithm. Individual written reprots will be due on Wed. of Finals week.

While there is no text book for the class, there are a number of remote sensing books that students may avail themselves of.

- Stephens, G., 1994: Remote Sensing of the Lower Atmosphere: An Introduction. Oxford University Press, Inc. 523pp.

- Rodgers, C., 2000: Inverse Methods for Atmospheric Sounding – Theory and Practice. World Scientific, Series on Atmospheric, Oceanic and Planetary Physics, Vol. 2. 240 pp.

- Elachi, C., 1987: Introduction of the Physics and Tech. of Remote Sensing, Wiley, 413 pp.

- Bringi, V. N., and V. Chandrasekar, 2001: Polarimetric Doppler Weather Radar. Cambridge University Press, 636 pp.

- Ulaby, F. T., R. K. Moore and A. K. Fung, 1981: Microwave Remote Sensing Vols I-III, Addison-Westy, 2161 pp.

In addition, there are a number of good textbooks covering the basic principles of atmospheric radiation:

- Liou, K. N., 2002: An Introduction to Atmospheric Radiation (second edition), Academic Press - International Geophysical Series, 583 pp.

- Petty, G. W, 2006: A First Course in Atmospheric Radiation (second edition). Sundog Publishing. Madison, Wisconsin.460pp. (www.sundogpublishing.com/AtmosRad.htm)

- Bohren, C. F. and D. R. Huffman, 1983: Absorption and Scattering of Light by Small Particles, Wiley, 530 pp.

- Goody, R. M. and Y. L. Yung, 1989: Atmospheric Radiation: Theoretical Basis, Oxford Univ. Press, 519 pp.

AT652 -- Atmospheric Remote Sensing
(Fall 2024; T/Th 9:00 - 9:50)

Aug 20/22

L01 – Intro to course, goals and expectations
L02 – Ground based and satellite instrumentation. Satellite orbits

Aug 27/29

L03 – Satellite orbits and the Gravity Recovery and Climate Exp. (GRACE)
L04 – Spatial, spectral and radiometeric resolution
Paper: Morrow et al., 2010: *Water Storage, Net Precipitation, and Evapotranspiration in the Mackenzie River Basin from October 2002 to September 2009 Inferred from GRACE Satellite Gravity Data*

Sept 3/5

L05 – The origins of EM radiation, the electromagnetic spectrum and Beer's law
L06 – Land Surface properties
Paper: *Morris and Ruf, 2017: Determining Tropical Cyclone Surface Wind Speed Structure and Intensity with the CYGNSS Satellite Constellation*

Sept. 10/12

L07 – Atmospheric absorption & emission
L08 – Atmospheric absorption and radio occultation measurements
Paper: *Kursinski, 2002: Microwave Occultation Observing System Optimized to Characterize Atmospheric Water, Temperature, and Geopotential via Absorption.*

Sept 17/19

L09 – Atmospheric soundings
L10 – A first look at Optimal Estimation (OE) solutions
Paper: *Duncan, 2016: A 1DVAR Retrieval Applied to GMI: Algorithm Description, Validation, and Sensitivities*

Sept 24/26

L11 – Dielectric media and scattering
L12 – Single particle and ensemble scattering
Paper: *Meyer, 2004: Optical Thickness of Tropical Cirrus Clouds Derived from the MODIS 0.66- and 1.375-μm Channels.*

Oct 1/3

L13 – Radar remote sensing
L14 – Lidar remote sensing
Paper: *Mace, 2013: The CloudSat Radar-Lidar Geometric Profile product (RL-GeoProf): Updates, Improvements and Selected Results.*

Oct 8/10

L15 – Current retrieval papers and their foundations
L16 –Optimal Estimation revisited
Paper: *Boukabara, 2011: MiRS: An All-Weather 1DVAR Satellite Data Assimilation and Retrieval System.*

Oct. 15/17

L17 – Bayes's theorem and precipitation retrievals
L18 – Precipitation and W&E cycle variables.
Paper: *Yu, 2007: Global Variations in Oceanic Evaporation (1958-2005): The Role of the Changing Wind Speed.*

Oct 22/24

L19 – W&E budgets and their closure
L20 – Data Fusion – IMERG & Discussion of Fusion Project

Oct 29/31 (Guest Lectures, Simon Pfreundschuh)
L21 – AI and Machine Learning
L22 – AI and Machine Learning

Nov 5/7

L23 – Image enhancement techniques
L24 – Products developed from imagery
Paper: *Miller, 2013: Illuminating the Capabilities of the Suomi National Polar-Orbiting Partnership (NPP) Visible Infrared Imaging Radiometer Suite (VIIRS) Day/Night Band.*

Nov 12/14

25 – Student Fusion Project Presentations & Final project discussion: building a retrieval algorithm
26 – Final Project preparation

Nov 19/21 (Guest Letures – Chris O'Dell)
27 – Introduction to CO_2 problem
28 – Remote Sensing of CO_2

Nov 26/28 Fall Recess

Dec 3/5

29 – Validation: Are we on the right track?
30 – From products to process. New missions on the horizon

Dec 9-13 Finals week. Project due by 5pm on Wed., Dec. 11.