Lidar Remote Sensing: Outline for Class 2008

Lecture 1. Introduction to Lidar Remote Sensing Class **8/25**

What is LIDAR?
Current Lidars and Future Potentials
Course Structure and Contents
Plans for final projects
Instructor and Her lidar group
Summary + References

Lecture 2. Introduction to Remote Sensing **8/27**

Concept and Picture of Remote Sensing
Content of Remote Sensing
Classification of Remote Sensing
Passive Remote Sensing
Active Remote Sensing
Comparison of Remote Sensing
Summary

Lecture 3. Fundamentals of Lidar Remote Sensing (1) **8/29**

Introduction
History from Searchlight to Modern Lidar
Various Modern Lidars
Altitude and Range Determination
Summary

Lecture 4. Fundamentals of Lidar Remote Sensing (2) **9/3**

Introduction
Physical Picture of Lidar Equation
Fundamental Lidar Equation
Different Forms of Lidar Equation
Illustration of Lidar Equation
Summary

Lecture 5. Fundamentals of Lidar Remote Sensing (3) **9/5**

General illustration of lidar equation
Overview of physical processes in lidar
Elastic and inelastic scattering vs polarization
Absorption and differential absorption
Fluorescence and resonance fluorescence
Comparison of backscatter cross section
Doppler effect and Boltzmann distribution
Summary

Lecture 6. Fundamentals of Lidar Remote Sensing (4) **9/8**

Review physical processes in lidar equation
Example calculation in physical processes
Solution for scattering form lidar equation
Solution for fluorescence form lidar equation
Solution for differential absorption lidar equation
Solution for resonance fluorescence lidar
Solution for Rayleigh and Mie lidar
Summary

Lecture 7. Fundamentals of Lidar Remote Sensing (5) **9/10**

Basic Lidar Architecture
Configurations vs. Arrangements
A Real Example: Arecibo K Doppler Lidar
Transceiver with HOE
Lidar Classifications

Summary

Lecture 8. Lidar Simulation - Application of Lidar Equation **9/12**

Review lidar fundamentals
How to start lidar simulation?
Lidar parameters and atmosphere parameters
Simulation of resonance fluorescence return
Simulation of Rayleigh scattering return
K lidar signal estimate from lidar equation
Summary

Lecture 9. Lidar Simulation and Error Analysis Overview **9/15**

Review lidar simulation (non-range-resolved)
Overview of lidar simulation and error analysis
Range-resolved lidar simulation procedure
Summary

Lecture 10. Topical Lidar Overview **9/17**

Review range-resolved lidar simulation
What are topical lidars and why?
Temperature techniques
Wind techniques
Aerosol techniques
Constituent techniques
Target & altimeter techniques
Summary

Lecture 11. Temperature Lidar (1) **9/19**
Overview and Doppler Technique

Overview of temperature measurement techniques
Doppler technique for temperature and wind measurements
Resonance fluorescence Na Doppler lidar
Summary

Lecture 12. Temperature Lidar (2) **9/22**
Doppler Ratio Technique

Review Doppler Technique
Scanning technique vs. ratio technique
Principle of Doppler ratio technique
Comparison of calibration curves
Other resonance fluorescence Doppler lidars
Summary

Lecture 13. Lidar Data Retrieval (1) **9/24**

Introduction of data inversion
Basic ideas (clues) for data inversion
Preprocess
Summary

Lecture 14. Lidar Data Retrieval (2) **9/26**

Review of Preprocess
Main Process Procedure to Derive T and V_R using Ratio Doppler Technique
Derivation of n_c from narrowband resonance Doppler lidar
Derivation of β
Derivation of n_c from broadband resonance lidar
Summary

Lecture 15. Temperature Lidar (3) **9/29**
Resonance Fluorescence Doppler Lidar Instrumentation

Review Doppler ratio technique
Na Doppler lidar instrumentation
- Absolute frequency calibration – Doppler-free spectroscopy

- AOM, pulsed dye amplification
- Faraday filter for daytime observations
Comparisons among Na, K, and Fe Doppler lidars
Summary

Lecture 16. Temperature Lidar (4) **10/1**
Rayleigh Doppler Technique

Frequency analyzer in receiver
Rayleigh Doppler lidar
High-spectral-resolution lidar
DIAL temperature technique
Summary

Lecture 17. Temperature Lidar (5) **10/3**
Boltzmann Technique and Rotational Raman Technique

Introduction
Boltzmann temperature technique
Fe Boltzmann temperature lidar
N2+ Boltzmann temperature lidar
Rotational Raman technique
Summary

Lecture 18. Temperature Lidar (6) **10/6**
Integration Technique

Review Doppler and Boltzmann techniques
Integration technique for temperature
Searchlight integration lidar
Rayleigh integration temperature lidar
Vibrational Raman integration lidar
Falling sphere temperature measurement
Rayleigh/Raman lidar instrumentation
Comparison of temperature techniques
Summary

Lecture 19. Wind Lidar (1) **10/8**
Overview and Vector Wind

Motivations to measure global wind
Overview of wind measurement techniques
- Direct Motion Detection Technique
- Coherent Detection Doppler wind technique
- Direction Detection Doppler wind technique
- Geostrophic wind technique
Vector Wind Determination
Summary

Lecture 20. Wind Lidar (2) **10/10**
Direct Motion Detection Wind Lidar

Direct Motion Detection Wind Lidar
Lidar tracking of aerosol motions
Laser Time-of-Flight Velocimetry
Laser Doppler Velocimetry
Coherent versus Incoherent Detection
Doppler wind lidar techniques
Summary

Lecture 21. Wind Lidar (3) **10/13**
Direct Detection Doppler Lidar

Overview of Direct Detection Doppler Lidar (DDL)
Resonance fluorescence DDL
Fringe imaging DDL

Scanning FPI DDL & FPI edge-filter DDL
Iodine absorption-line edge-filter DDL
Na or K DEMOF DDL
New development of DDL at the 24th ILRC
Comparison of Wind Techniques
Summary

Lecture 22. Wind Lidar (4) **10/15**
Optical Remote Sensing with Coherent Doppler Lidar
Mike Hardesty's Guest Lecture
Part 1. Background and Doppler Lidar Hardware

Introduction of Coherent Doppler Lidar
Coherent (Heterodyne) Detection
Laser (HRDL, MOPA)
Transmit/Receive paths
Atmosphere

Lecture 23. Wind Lidar (5) **10/17**
Optical Remote Sensing with Coherent Doppler Lidar
Mike Hardesty's Guest Lecture
Part 2. Detection, Processing, and Analysis of Lidar Signals

Detection & Processing
Analysis and Data products
Field Work (3 application examples)
- Wind turbine
- Shipborne
- Airborne

Lecture 24. Polarization Detection by Lidar **10/20**
Gary Gimmestad Guest Lecture:
Polarization Considerations in Lidar Measurements

Lecture 25. Aerosol Lidar (1) **10/22**
Overview and Polar Mesospheric Clouds

Motivations to study aerosols and clouds
Lidar detection of aerosols and clouds
Polar mesospheric clouds (PMC) detection by lidar
PMC physical properties
PMC chemistry role in upper atmosphere
PMC relation to atmospheric dynamics
PMC microphysical properties detected
by multi-wavelength and polarization lidar
Summary

Lecture 26. Aerosol Lidar (2) **10/24**
Elastic-Scattering Lidar, Raman Lidar, and HSRL

Elastic-scattering lidar for aerosol detection
Single-channel vs multi-channel aerosol lidar
Measurement of aerosol extinction from multichannel lidar (Raman & HSRL)
High Spectral Resolution Lidar (HSRL)
University of Wisconsin HSRL example
Comparison of aerosol lidar technique
Summary

Lecture 27. Lidar Simulation and Error Analysis: Range-Resolved **10/27**

Review the overview of lidar simulation and error analysis (from Lecture 9)
Lidar simulation contents and steps
Range-resolved lidar simulation
Error analysis for photon noise

Summary

Lecture 28. Lidar Error Analysis and Sensitivity Analysis **10/29**

Introduction
Accuracy versus Precision
Classification of measurement errors
Accuracy in lidar measurements
Precision in lidar measurements
Error analysis and sensitivity analysis
Summary

Lecture 29. Constituent Lidar (1) **10/31**

Overview of Resonance Fluorescence Lidar, DIAL and Raman

Motivations to study atmosphere constituents
Lidar detection of constituents
(spectroscopic signatures to distinguish species)
Metal atoms by resonance fluorescence lidar
DIAL detection of molecules and pollutant
(DIAL equation and solution)
Raman lidar detection of molecules and pollutant
(Raman equation and solution)
Summary

Lecture 30. Constituent Lidar (2) **11/3**

Christoph Senff Guest Lecture: Optical Remote Sensing with Differential Absorption Lidar (DIAL)

DIAL concept
A short history of DIAL
DIAL equation, error analysis, and system components
DIAL systems at NOAA/ESRL/CSD
Multi-wavelength ozone DIAL
Applications of airborne ozone DIAL

Lecture 31. Constituent Lidar (3) **11/5**

Raman Lidar and Raman DIAL

Introduction
Fundamentals of Raman Scattering
Raman Lidar Technical Requirements
Raman Lidar Measurements of Water Vapor
Raman DIAL for Ozone Measurement
Summary

Lecture 32. Constituent Lidar (4) **11/7**

Multi-wavelength Raman DIAL

Review conventional Raman DIAL
Rotational vibrational-rotational (RVR) Raman DIAL
Multiwavelength DIAL
Comparison of Constituent Lidar Techniques
Summary for Constituent Lidar

Lecture 33. Spaceborne Lidar (1) **11/10**

Carl Weimer's Guest Lecture: CALIPSO On-Orbit - Lidar

Why CALIPSO?
Some Early Science Results
Selected Engineering Results

Lecture 34. Target Lidar (1) **11/12**

Laser Induced Fluorescence Lidar

Motivations for target lidar
Fluorescence spectroscopy
Fluorescence lidar principles

Ground-truth fluorosensor – point monitor
Applications of fluorescence lidars
1) Marine monitoring
2) Vegetation monitoring
3) Historical monument
Summary

Lecture 35. Target Lidar (2) **11/14**
Laser Rangefinding & Laser Altimeter

Laser Rangefinding Techniques
1) Time of Flight
2) Geometry-based
3) Interferometry
Laser altimeter
Lidar remote sensing of snow depth
Summary of target lidar

Lecture 36. Spaceborne Lidar (2) **11/17**
Waleed Abdalati's Guest Lecture: NASA's Ice Cloud and land Elevation Satellite (ICESat)

Lecture 37. Lidar Architecture and Lidar Design (1) **11/19**

Introduction
Lidar Architecture: Configurations & Arrangements
Examples of Real Lidars
Lidar Design: Basic Ideas & Basic Principles
Summary

Lecture 38. Lidar Architecture and Lidar Design (2) **11/21**

Introduction
Lidar Design: More Details
Examples
Summary

Lecture 39. Lidar Class Review (1) **12/1**

Overview and clue of lidar class
Concept and picture of lidar remote sensing
General lidar equation and basic assumptions
Physical processes involved in lidar
Lidar equation in different forms
Lidar architecture
Altitude and range determination
Lidar calibration considerations

Lecture 40. Lidar Class Review (2) **12/3**

Temperature lidar
Wind lidar
Aerosol lidar
Constituent lidar
Target lidar
Accuracy versus precision
Lidar simulation and error analysis
Lidar design considerations
Summary and outlook

Lecture 41. LIDAR Future Outlook **12/5**

What's new and what's happening out there?
While-light lidar
Future potentials and growing points