Atmospheric Lidar Based Remote Sensing Techniques

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Contents

◆ Atmospheric properties

◆ Atmospheric detection principle using lidar

◆ Versatility of lidar application platforms

◆ Interpretation of lidar data

◆ My future work
Various layers in the atmosphere accessible to lidar researchers
Interaction between atmosphere and people

global warming
hazy weather
human health
dust storm
air pollution
Observation tools and their corresponding detection range

- **Satellite:** >50km
- **Rocket:** 50km
- **Radiosonde:** >40km
- **Aircraft:** <15km
- **Radar:** <10km
- **Lidar:** >50km
Advantages of lidar remote sensing

LIDAR (Light Detection And Ranging):
- **High spatial and temporal resolution** of the measurements;
- The potential for covering the **height** (>100 km);
- The variety of detection, **temperature, pressure, humidity** and **wind**, as well as the measurement of **trace gases, aerosols** and **clouds**.
Light propagation in the atmosphere

Type of atmospheric scattering effect

<table>
<thead>
<tr>
<th>Types</th>
<th>Wavelength Relationship</th>
<th>Detection component</th>
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<tbody>
<tr>
<td>Mie</td>
<td>Elastic</td>
<td>$\lambda_i = \lambda_s$</td>
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<tr>
<td>Rayleigh</td>
<td>Elastic</td>
<td>$\lambda_i = \lambda_s$</td>
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<tr>
<td>Raman</td>
<td>Inelastic</td>
<td>$\lambda_i \neq \lambda_s$</td>
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Spectrum of lidar return signal using 354.7 nm excitation laser
Elastic scattering

- Aerosols: diameter of about 100 μm, suspended in the atmosphere, liquid or solid particles;
- Include: ground dust, dust storms, forest, fire shot, pollen, and other gaseous pollutants;
- Influence: climate change, cloud formation, visibility changes and human health.
Spherical and non-spherical particles depolarization

- Liquid particles: Spherical and no-depolarization
- Solid particles: non-spherical and depolarization
Lidar system

Schematic diagram of lidar system

Perspective view of lidar system

**Spectroscopic system:**
Grating, Prism, Interference Filter, Fiber Bragg Grating

**Detector:**
Photomultiplier Tube (PMT), Avalanche Photodiode (APD), Charge-coupled Device (CCD)

**Data recorder:**
Data Acquisition Board (DAQ)
The lidar return signal

The range-corrected signal/w

The original lidar signal

The range-corrected lidar signal

The amplitude of the range-corrected signal is roughly proportional to the density of molecules or aerosol loading.
State of the art

- In the future studies of lidar: Optical properties of aerosol, Field of wind, temperature and humidity.

- Global fixed-point observation network:
  - The European Aerosol Research Lidar Network (EARLINET);
  - Micro Pulse Lidar Network (MPLNET) by NASA 2010;
  - AD-net in East of Asia, based sandstorm observation.

- Furthermore, focus on the purpose for the needs of different applications, developing into multi-platform support (ground, vehicle, airborne, spaceborne and so on). United States, Europe and China etc. developed their spaceborne lidar system.
Diversified Application Platform

Ground-based lidar

Inclination detection

Vertical detection
Ground-based lidar at Otlica observatory
Scanning lidar

Spatial coordinate obtained by 3D lidar

Three-dimensional scanning lidar
Airborne application of lidar
NASA equipped The UAV platform with differential absorption lidar for measurements of atmospheric water vapor in 1999.
Spaceborne application of lidar

Aerosol - Cloud Lidar was launched by NASA in 2006.

Europe will launch a wind lidar system named ADM-Aeolus in 2015.
The lidar measurements
Time-Series Measurement

Measurements taken in Ljubljana:

THI (Time-Height-Indication)
Horizontal scanning

Measurements taken in Nova Gorica:
Horizontal scanning

Suburbs

Highway

PPI (Plane-Position-Indication)
Using both the PPI and RHI scanning mode we can obtain 3D field.
Detection of atmospheric temperature and water vapor

Spectroscopic system

Raman spectras

The schematic diagram of a spectroscopic system
Raman Lidar

Rotational Raman lidar from Germany GKSS
Height: 40 km; error: 1 K

Rotational Raman lidar from University of Pennsylvania State LAPS
Error: 0.3 K (below 1 km)
Rotational raman lidar for temperature measurements

Profile of temperature taken by lidar (left), THI of temperature during 20:00~23:00 on June 30, 2013 (right). Measurements taken in Xi'an.
Vibrational raman lidar for the measurements of density of water vapor

THI of water vapor density during 19:25~23:00 in the night. Measurements taken in Xi'an.
Wind Lidar service in the Olympics

Provided highly accurate wind speed and direction tracking information on sea surface in 2008, Qingdao, China.
Wind Lidar

Wind speed and direction detected by lidar
Air pollution detection

- **Polluting gases:**
  - NO\textsubscript{x}, SO\textsubscript{2}, O\textsubscript{3}, CO, CH\textsubscript{4}

- **Detection tool:**
  - Differential absorption lidar

- **LD pumped solid-state laser technology:**
  - using a tunable laser in wavelength range from 2 ~10 \( \mu \)m.
Fluorescence Lidar

Vegetation: based on a linear relationship between fluorescence (laser-induced) and the density of organic matter

Biological aerosol detection:
The growing condition of plant and water algae; organic pollutants; the pollens and other organic particles
My future work

1. Set up depolarization aerosol lidar

- Detecting the particle morphology of non-spherical particles;
- As a long-term observations, analysing the composition of aerosols in Slovenia;
- Statistical data from seasons, provides reference for special structure of atmospheric aerosol layer (dust layer).

Schematic diagram of depolarization lidar system
2. Measurements of Bora wind using rapid scanning lidar

- Get the profile of wind speed and direction of Bora wind (vertical information)

- With the scanning mode, get a 2D wind field profile (zenith and azimuth scanning modes)

Using existing platforms (Raman, Mie and depolarization lidar from Otlica), study of the impact of the local wind on the aerosols.
References


Thank you for your attention