ID.10532 Atmospheric Dynamics from LIDAR
The Research from Vehicle-mounted to Space-borne Doppler Wind LIDAR

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Team Composition

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Project Objectives

We will provide an independent and credible measurement of radial wind speed, wind profile, 3D wind vector, aerosol-backscatter ratio aerosol extinction coefficient, extinction-to-backscatter ratio (limited in the atmospheric boundary layer and troposphere), sea surface wind vectors using the direct-detect Doppler wind lidar / HSRL (High Spectral Resolution Lidar) with an iodine filter during ADM-Aeolus overpass ground-based lidar site (N 36.04, E 120.20). In addition to the lidar observations, wind profiles and other relevant meteorological data from radiosonde could also be provided. These results can be compared with the data products of ADM-Aeolus, and we will analyze the comparison results and present assessment reports to ESA.
Validation mode

Ground based Mobile Doppler lidar

ADM-Aeolus
Doppler wind lidar based on iodine filter

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**Transmittance**

- **Transmittance** vs **Frequency**
  - **Δν_{DOP}**
  - **ν₀**, **ν_R**
  - **Aerosol**
  - **Molecular**
  - **ΔT**

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**Nd:YAG Pulsed Laser (Injection Seeded)**

**Transmitting Subsystem**

- **BS**: Beamsplitter
- **M**: Mirror
- **L**: Lens
- **IF**: Interference Filter
- **NPBS**: Non-Polarizing BS
- **PMT**: Photomultiplier

**Receiving Subsystem**

- **PMT1**
- **Iodine Filter**
- **NPBS**
- **PMT2**
- **IF**
- **L₂**
- **Fiber**

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**Elevation-over-Azimuth Scanner**

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**Schmidt-Cassegrain Telescope**
aerosol backscatter ratio \( R_b = \frac{\beta_a}{\beta_m} \)

- aerosol volume backscatter coefficients
- molecular volume backscatter coefficients

\[
\begin{align*}
\text{Height (km)} & \quad 0 & 5 & 10 & 15 \\
\text{Photon Counts} & \quad 10^1 & 10^2 & 10^3 & 10^4 & 10^5 & 10^6 & 10^7 & 10^8 \\
\text{Normalized Transmission} & \quad 0 & 0.1 & 0.2 & 0.3 & 0.4 & 0.5 & 0.6 & 0.7 & 0.8 & 0.9 & 1 \\
\text{Relative Frequency (GHz)} & \quad -3 & -2 & -1 & 0 & 1 & 2 & 3
\end{align*}
\]
• Ground based Doppler wind lidar

Wind profile measurements

Doppler lidar in container

Daytime operation

The daytime operation within a range of 12 km is achieved by
– matching of divergence and field of view
– using fiber to restrain near-field light
– using interference filter with narrow bandwidth
Compact and Modular Design
Mobile Doppler lidar

- 3-Dimensional wind field measurements including:
  - Wind profile
  - Horizontal wind distribution

<table>
<thead>
<tr>
<th>Transmitting subsystem</th>
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<tbody>
<tr>
<td>Wavelength</td>
<td>532 nm</td>
</tr>
<tr>
<td>Repetition rates</td>
<td>500 Hz</td>
</tr>
<tr>
<td>Pulse energy*</td>
<td>3 mJ</td>
</tr>
<tr>
<td>Line width</td>
<td>&lt;100 MHz</td>
</tr>
<tr>
<td>Spectral purity</td>
<td>&gt; 99.9%</td>
</tr>
<tr>
<td>Divergence</td>
<td>100 μrad</td>
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<table>
<thead>
<tr>
<th>Receiving subsystem</th>
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<tbody>
<tr>
<td>Field of view</td>
<td>200 μrad</td>
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<tr>
<td>Interference filter bandwidth</td>
<td>0.11 nm</td>
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<tr>
<td>Interference filter peak transmission</td>
<td>76%</td>
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<tr>
<td>PMT quantum efficiency</td>
<td>0.1</td>
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</table>

<table>
<thead>
<tr>
<th>Telescope and scanner subsystem</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Aperture of scanner</td>
<td>320 mm</td>
</tr>
<tr>
<td>Aperture of telescope</td>
<td>305 mm</td>
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</table>
Example of wind profile

Radiosonde launch time: 19:15,
lidar measurement time: 19:30–19:38,
Blue shadow (3.95-6.25 km) shows
height cover range of radiosonde
during lidar measurement.

Wind profile measured by lidar (blue)
and radiosonde (red) in 18 April 2011.
Statistics of wind profiles

ALL
n=3765
RMS 2.76 m/s

AM
n=1671
RMS 2.95 m/s

PM
n=2074
RMS 2.59 m/s

Bias = 0.75 m/s

Bias = 1.28 m/s

Bias = 0.32 m/s
Sea surface wind

**Directional measurement:**
zero wind ratio $r_0$, sensitivity $S$

**Scanning measurement:**
wind ratio $R_{W,i}$

\[ V_{LOS,i} = \frac{R_F}{S} = \frac{R_{W,i} - r_0}{r_0 S} \]

LOS velocity (with systematic bias)

VAD calibration \rightarrow Removing systematic bias

LOS velocity

VAP method \rightarrow Horizontal wind vector (at height $h$)

Height adjustment \rightarrow Horizontal wind vector (at 10m height)
Example of sea surface wind before rain (LOS velocity)
August 18, 2007  08:10~08:30 (Time interval: 2 min)
Experiment period:
1. August 8~23
2. September 6~13

Meteorological Service for 2008 Olympic Sailing Game
Wind profile measurements during spacecraft landing

Wind profiles before landing of Shenzhou 7
New technology may help Olympic sailing

A team of researchers at the Ocean University of China has developed and tested a mobile LIDAR (Light Detection and Ranging) station that can accurately measure wind speed and direction over large areas in real time—a application useful for aviation safety, weather forecasting, and sports.

As described in the July 1 issue of the journal Optics Letters, published by the Optical Society, the mobile LIDAR station can measure wind fields more accurately, which could help world-class athletes compete in international competitions such as the Olympics. Ocean University is in Qingdao, which is hosting the sailing competitions of the 2008 Olympic Games and the Sailing World Cup. Learn more about this technology in today's news.
Moving measurements of the Mobile Doppler LIDAR
Wind profile (VAD method)

Elevation: 45°  
Radius: 10 km

LOS velocity (m/s)

Wind Direction (°)

Wind Speed (m/s)

Height (km)
### Aircraft: Y-12

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<tr>
<th>Parameter</th>
<th>Value</th>
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<td>Maximum altitude</td>
<td>3500 m</td>
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<tr>
<td>Maximum take-off weight</td>
<td>5.3 ton</td>
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<tr>
<td>Actual flight altitude</td>
<td>3000 m</td>
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<tr>
<td>Aircraft net weight</td>
<td>4.6 ton</td>
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<tr>
<td>Flight range</td>
<td>15000 km</td>
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<tr>
<td>Speed</td>
<td>250 km/h</td>
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<tr>
<td>Payload</td>
<td>0.7 ton</td>
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<tr>
<td>Actual speed</td>
<td>200 km/h</td>
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</table>
Airborne measurements

cross section of wind ratio

wind ratio with altitude
Spaceborne Wind Lidar Simulation

45° 斜角

True Los wind speed
Simulated Los wind speed

135° 斜角

True Los wind speed
Simulated Los wind speed

FP
FP自由光谱范围/GHz
12
FP峰值透过率
0.8
FP半高全宽/GHz
1.7

激光带宽/MHz
90
激光波长/nm
355

温度/K
280
测量脉冲数
100

激光能量/J
0.15
分辨率/m
1000

分光比
0.5
接收视野角
0.07

透镜面积/m^2
1.5
背景滤波器带宽
0.1

光学效率和量子效率
0.56

后向散射及消光系数路径
E:\仿真模拟\simulation\data\%
后向散射比路径
E:\仿真模拟\Rb\%
数据保存路径
新建 文本文档.txt
Spaceborne Wind Lidar Simulation

Simulated Wind Error

ALADIN Wind Error by ESA
Conclusions

• Ground based Doppler lidar for measuring wind profile was developed.
• Mobile Doppler lidar was developed for wind profile and 3D wind field measurements.
• Airborne Doppler lidar for measuring wind profile was tested.
• Simulation of spaceborne Doppler lidar was performed.
Thank you for your attention!