Aeolus – ESA’s Wind Lidar Mission:
Objectives, Design & Status

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Working Group on Space-based
Lidar Winds
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Atmospheric Dynamics of the Earth

- Polar cell
- Polar jet
- Ferrel cell
- Subtropical jet
- Hadley cell
- NE Trade Winds
- ITCZ
- SE Trade Winds
- Westerlies
- Easterlies
Aeolus: Mission Objectives

**Scientific objectives**
- To improve the quality of weather forecasts;
- To advance our understanding of atmospheric dynamics and climate processes;

**Explorer objectives**
- Demonstrate space-based Doppler Wind LIDARs potential for operational use.

**Observation means:**
- Provide global measurements of horizontal wind profiles in the troposphere and lower stratosphere

**Payload**
- ALADIN: Atmospheric LAser Doppler INstrument
Mission Design

Mission Parameters

- Orbit: sun-synchronous
- Mean altitude: ~400 km
- Local time: 18:00 ascending node
- Inclination: 96.97°
- Repeat cycle: 7 days / 109 orbits
- Orbits per day: ~16
- Mission lifetime: 3 years
Mission Design

18:00 Local Time Ascending Node

Earth rotation

Flight altitude 400 km

Sun

Flight direction

Line of sight

285 km

1 observation 87 km

Measurement track
Satellite Control

Ground station at Salmijärvi (Kiruna)

Satellite Control from ESOC Darmstadt (Germany)
Data Reception & Processing (1/2)

Data reception at Svalbard

Data processing at Tromsø

Wind data assimilation at ECMWF
Aeolus: Instrument Data Processing

Data preparation

Wind Velocity

AISP → L0 → L1A → L1B → L2B

L2B

v_{HLOS}

L2A

\beta, \sigma
Aeolus: Measurement Principle (1/2)

- Direct detection UV Doppler wind Lidar operating at 355 nm and 50 Hz PRF in continuous mode, with 2 receiver channels

- Mie receiver to determine winds from aerosol & cloud backscatter

- Rayleigh receiver to determine winds from molecular backscatter

- The line-of-sight is pointing 35° from Nadir to obtain horizontal backscatter component

- The line-of-sight is pointing orthogonal to the ground track velocity vector to remove contribution from the satellite velocity
Aeolus: Measurement Principle (2/2)

**Mie channel:**
- Aerosol/cloud backscatter
- Imaging technique

**Rayleigh channel:**
- Molecular backscatter
- Double-edge technique
### Aeolus: Observational Requirements

<table>
<thead>
<tr>
<th></th>
<th>PBL</th>
<th>Troposphere</th>
<th>Stratosphere</th>
</tr>
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<tbody>
<tr>
<td>Vertical domain</td>
<td>[km]</td>
<td>0-2</td>
<td>2-16</td>
</tr>
<tr>
<td>Vertical resolution¹</td>
<td>[km]</td>
<td>0.5</td>
<td>1.0</td>
</tr>
<tr>
<td>Horizontal domain</td>
<td></td>
<td></td>
<td>Global</td>
</tr>
<tr>
<td>Number of profiles</td>
<td>[hour⁻¹]</td>
<td>&gt;100</td>
<td></td>
</tr>
<tr>
<td>Horizontal track data availability</td>
<td></td>
<td>&gt; 90%</td>
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<tr>
<td>Temporal sampling</td>
<td>[hr]</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Horizontal resolution / integration length²</td>
<td>[km]</td>
<td>15 (target) – 100 (threshold)</td>
<td></td>
</tr>
<tr>
<td>Horizontal sub-sample length</td>
<td>[km]</td>
<td>km scale</td>
<td></td>
</tr>
<tr>
<td>Random error (HLOS Component)</td>
<td>[m/s]</td>
<td>1</td>
<td>2.5</td>
</tr>
<tr>
<td>Systematic error (HLOS component)</td>
<td>[m/s]</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Dynamic Range, HLOS</td>
<td>[m/s]</td>
<td>±150</td>
<td></td>
</tr>
<tr>
<td>Error Correlation per 100 km</td>
<td></td>
<td>&lt; 0.1</td>
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<tr>
<td>Probability of Gross Error</td>
<td>[%]</td>
<td>5</td>
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<tr>
<td>Timeliness</td>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Length of Observation Dataset</td>
<td>[yr]</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

¹ 24 atmospheric samples for Mie & Rayleigh channel with 0.25km minimum vertical resolution
² L1B data: ~90 km horizontal integration length
Aeolus: ALADIN Instrument

Optical Bench

Transmit-lasers

- The Master Oscillator is a stable resonator with an end-pumped rod. An RTP crystal q-switch is used. Pulses of about 5 mJ energy at 1065 nm are generated.
- Two diode pumped slab amplifiers generate about 350 mJ at 50 Hz pulse repetition frequency.
- These IR pulses are frequency tripled to the UV (355 nm) in two LBO crystals with ~40% efficiency.
- UV optics to shape and steer the output beam for compatibility with Aladin transmit optics.
Harmonic Conversion and UV section
Aeolus: Major events, Laser Test Experience

2005: Laser Diode Performance

2006: Optical Mount Instability

2008: LID of IR Optic Coatings

2009: LIC in Vacuum

2010: Long Term UV Energy Drift

2012: LID on UV Optic Coatings

2014: Features on UV Optic Coatings
Laser Endurance Test in Vacuum Chamber
150 M shots
Optical Bench Assembly (OBA) with Transmit & Receive Optics (TRO)
Optical Bench Fluence Test

Transmit Optics

Laser transmitter

ESA UNCLASSIFIED – For Official Use
1. **Instrument Functional Performance Tests (IFP) Aladin level**
   a. Primary and redundant lasers emitting via transmit optics and telescope to On Ground Support Equipment (OGSE). OGSE simulate atmospheric return signal through reception chain and spectrometers.

2. **Aladin Electromagnetic Compatibility (EMC) test** (Conducted emissions and susceptibility)

3. **System level initial functional and performance tests (IST1 & SVT1)**

4. **Satellite vibration, acoustic and shock tests**

5. **Satellite EMC test**

6. **Satellite Thermal Vacuum Test (Tvac) including**
   a. Functional and performance tests for hot and cold cases (IST2&3)
   b. ALADIN operating at full energy via OGSE

7. **System level final functional and performance tests (IST4 & SVT2)**
Aeolus: Mission Impact for Weather Forecast

The image illustrates the Earth's circulation patterns, including:
- Polar cell
- Polar jet
- Ferrel cell
- Subtropical jet
- Hadley cell
- ITCZ
- NE Trade Winds
- SE Trade Winds
- Westerlies
- Easterlies
Summary conclusions by two impact studies led by ECMWF and KNMI

- Especially beneficial in the tropics and at high altitudes
- HLOS winds provides approximately 75% of the full wind vector information
- Impact on forecast quality is of the same order as the currently available radiosonde observation network
- Impact rather insensitive to random wind error variation
- Even small wind biases can be detrimental, so try to reduce biases!

➤ Wind bias calibration efforts will be essential!
Conclusions

- More than 10 years of development challenges
- Invaluable experience has been gained
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- The mission remains worldwide unique
- Enthusiastic user communities anticipating break-through in weather forecast and climate research
- The Project and the Industrial team committed to complete Aladin by end 2015 and be ready for launch in 2016.
Important link:

- Aeolus Living Planet web site: [www.esa.int/The_Living_Planet_Programme/ADM-Aeolus](http://www.esa.int/The_Living_Planet_Programme/ADM-Aeolus)