Prospects and limitations of modern lidar systems for stratosphere and mesosphere research

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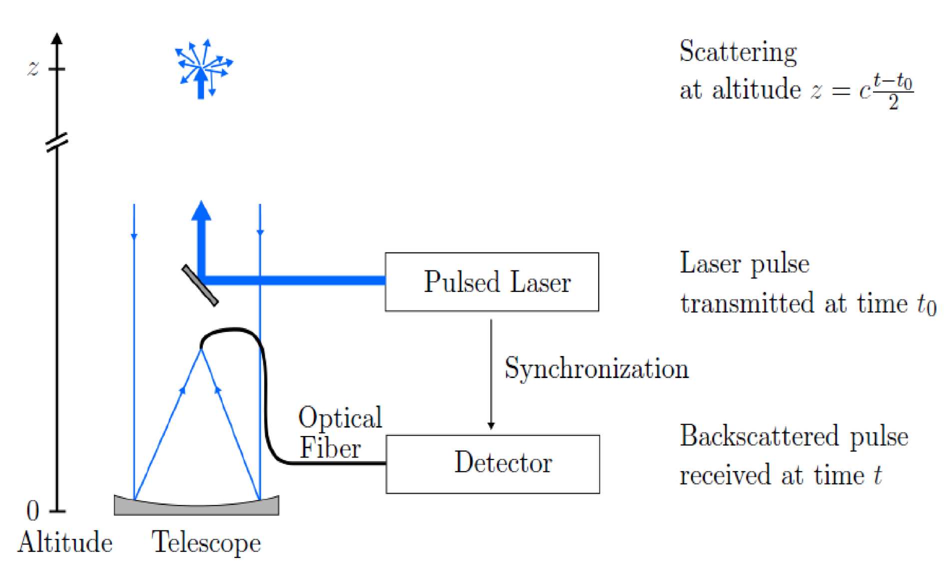
Introduction

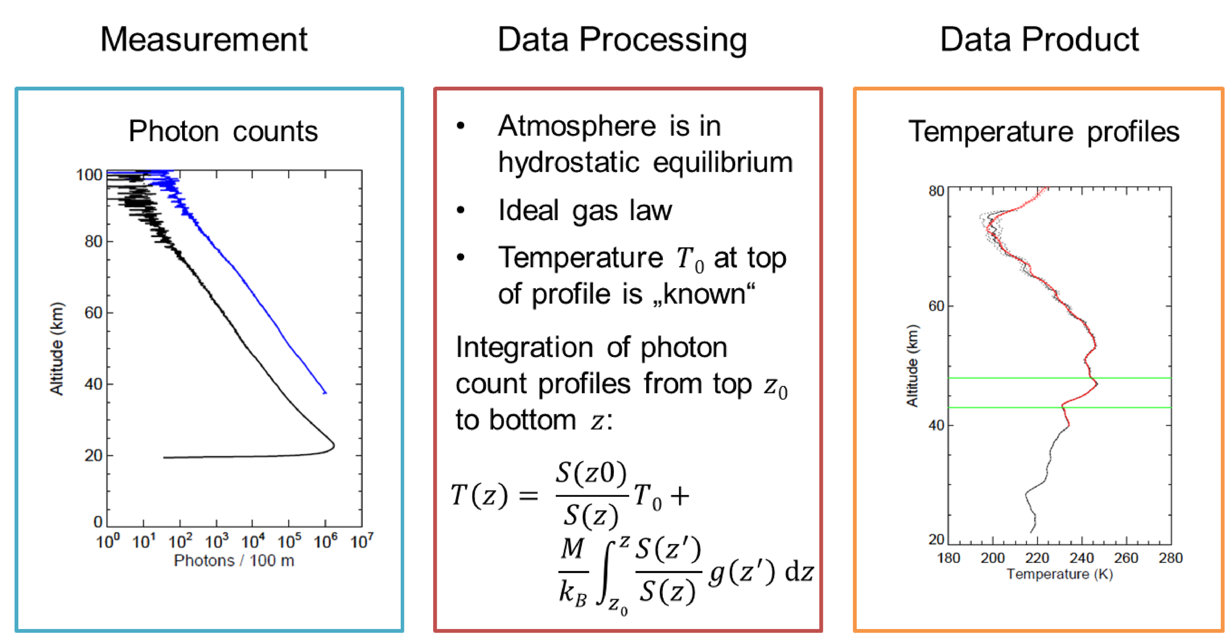
LIDAR (short for **Li**ght **D**etection **a**nd **R**anging) is the only tool which allows probing of the whole atmosphere from the ground up to about 120 km altitude.



Working principle of a LIDAR

The **Rayleigh LIDAR** technique uses backscattering from air molecules and allows retrieval of atmospheric temperature up to ~90 km altitude. However, because the air density decreases with increasing altitude, the signal-to-noise ratio becomes lower at higher altitudes and the time resolution decreases. One solution to this problem is the use of **resonance LIDARs** which detect photons scattered at metal atoms in global metal layers between 70 and 110 km altitude. Because resonant scattering is 16 orders of magnitude more efficient compared to Rayleigh scattering at air molecules, resonance LIDARs achieve much higher temporal resolutions in the order of several seconds to few minutes. This makes it possible to detect short-period internal gravity waves and possibly also acoustic waves.

Rayleigh Lidar Data Processing

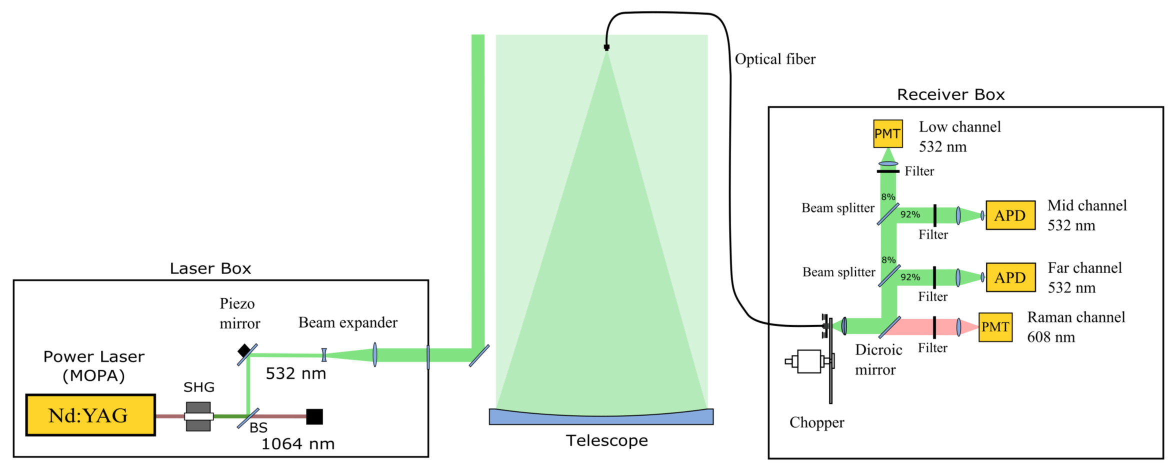


The Rayleigh temperature retrieval works only in the aerosol-free atmosphere above 30 km altitude. Temperature measurements below require Raman LIDARs or high spectral resolution LIDARs.

The Compact Rayleigh Autonomous LIDAR (CORAL)

CORAL is the first fully autonomous mobile LIDAR system for middle atmosphere temperature measurements.

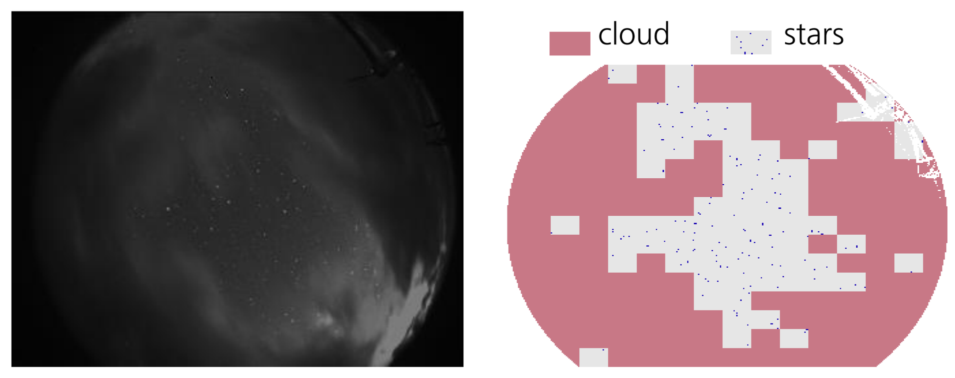
Laser	Diode pumped Nd:YAG, 12 W at 532 nm, 100 Hz PRF
Telescope	63 cm diameter, 240 µrad FOV



Schematic view of the CORAL optical system

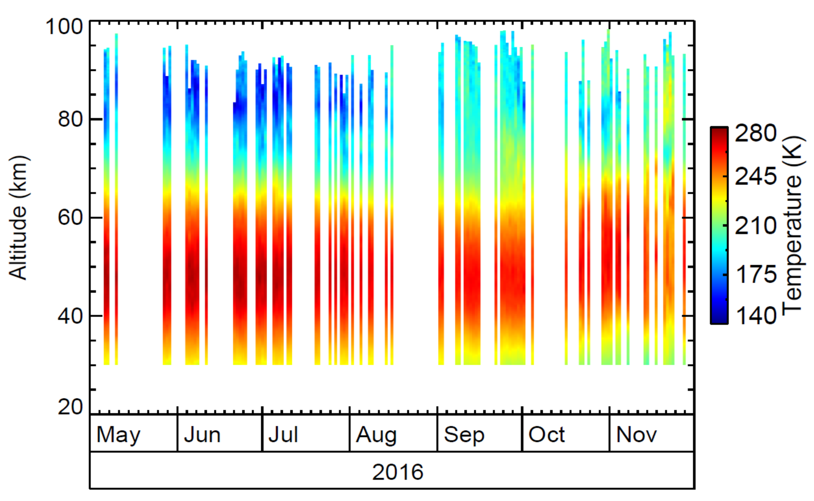
CORAL at the Sulzberg next to the GERES infrasound station in southern Germany

CORAL uses a weather station and cameras to monitor its environment. If all conditions are met (no rain, clear skies, no technical problems), computers start the LIDAR system shortly after sunset and stop just before sunrise. No human operator is needed.



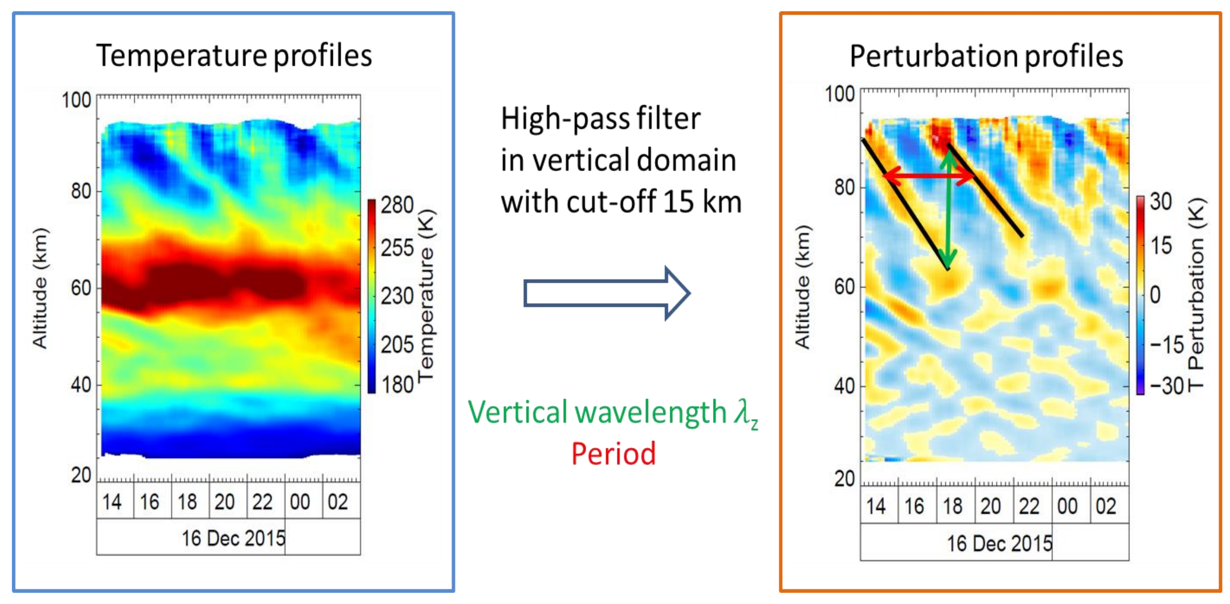
All-sky image and automatic cloud detection

CORAL Observations



Nightly mean temperature profiles acquired at the Sulzberg in southern Germany

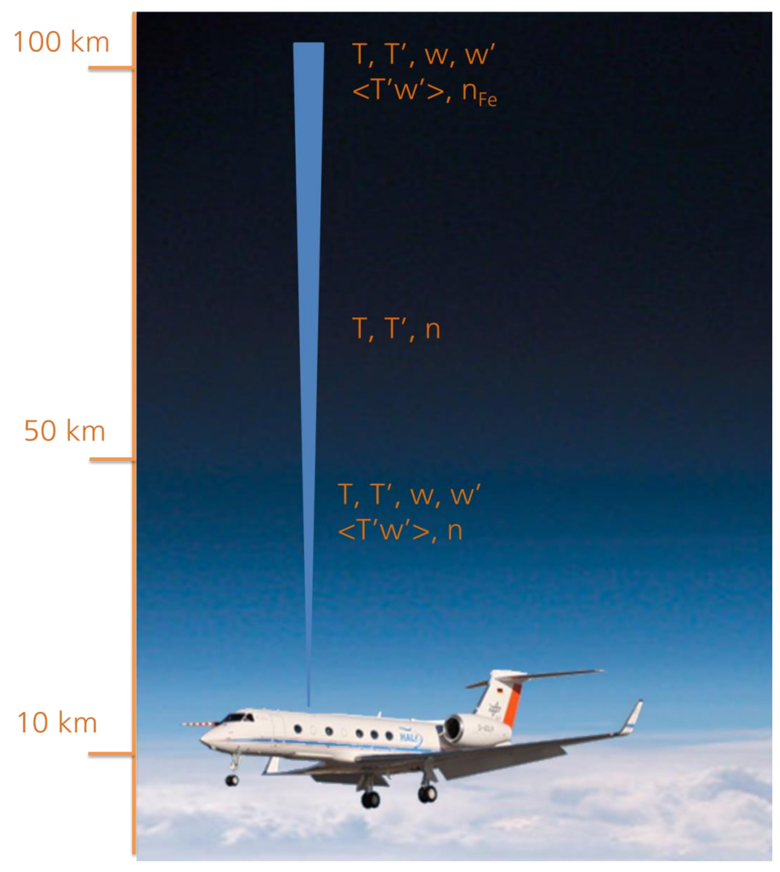
Extraction of Gravity Wave Signatures



Airborne LIDAR for Studying the Middle Atmosphere (ALIMA)

ALIMA is a powerful iron resonance LIDAR system currently in development at DLR. The ALIMA technology can be used to build very compact and highly capable autonomous middle atmosphere LIDARs.

- Temperature and vertical wind in the range 15-100 km with 30 seconds resolution
- Horizontal wind in ground-based configuration
- Doppler iron LIDAR (372 nm)
- Rayleigh wind LIDAR (558 nm)
- High-power laser: 8 W at 372 nm, 6 W at 558 nm
- 48 cm diameter telescope
- Narrow-band daylight filters
- Momentum flux measurements in ground-based configuration (two co-planar beams)
- First airborne measurement in 2019

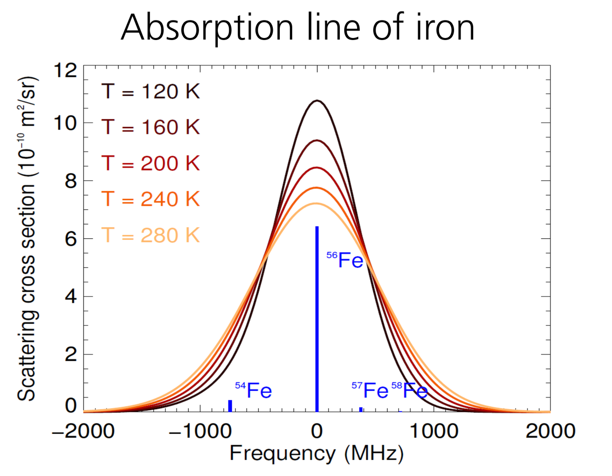


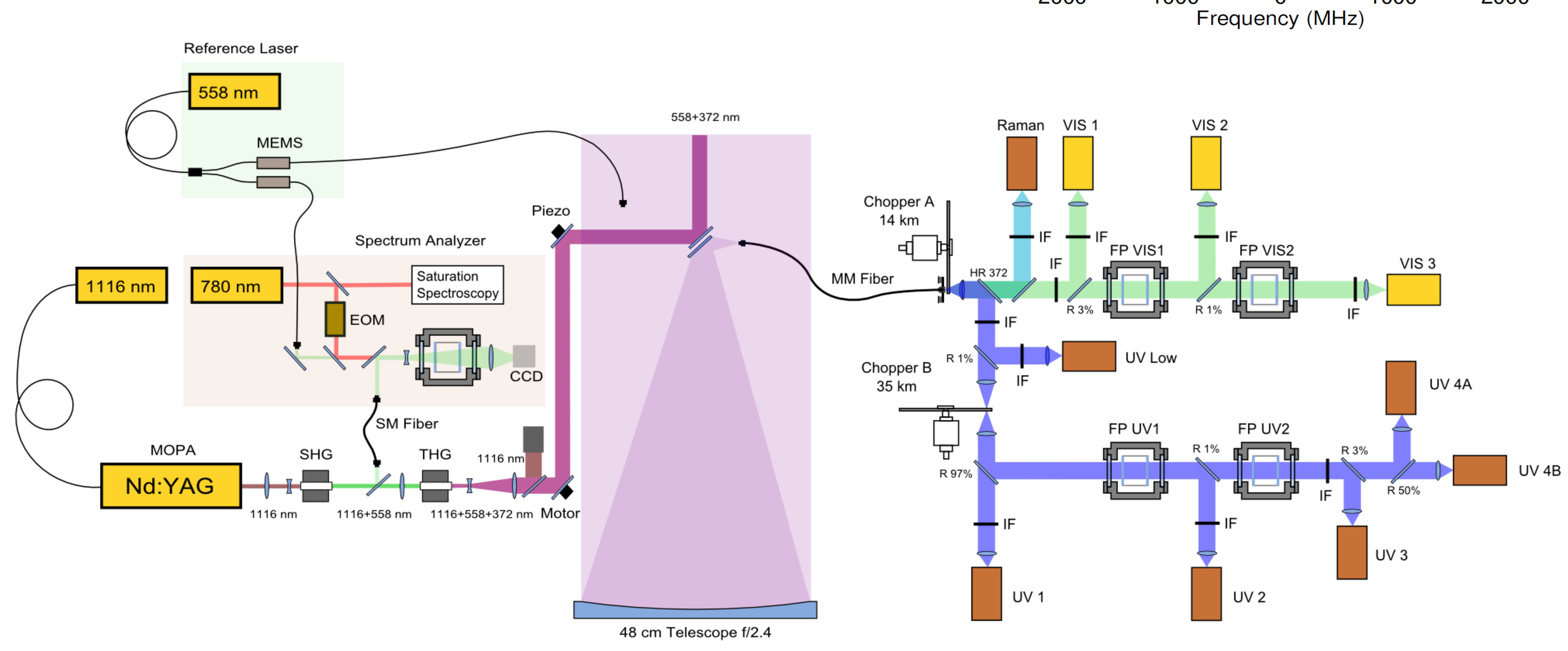
ALIMA onboard the research aircraft HALO

Measurement Principle

The Doppler-broadened absorption line of iron at 372 nm is probed with a tunable laser and the LIDAR return signal recorded as function of laser frequency. Temperature can be determined from the linewidth, wind speed from the frequency shift and iron density from the signal strength.

Absorption line of iron





Schematic view of the ALIMA optical system