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Environmental Research Solutions

In-Situ Laser Polarimetry for Cloud Microphysics: The Hyper-Angular Cloud Polarimeter (HACP)

HACP Series

The Hyper-Angular Cloud Polarimeter (HACP) is an advanced laser-based optical diagnostic system developed for high-resolution cloud microphysical analysis. It facilitates non-invasive, in-situ characterization of cloud particle ensembles by capturing detailed angular scattering and polarization signatures, thereby enabling rigorous quantification of size distributions, morphologies, and phase states across multiple observational geometries.

Cloud microphysical parameters such as effective radius and liquid water content are most commonly derived from satellite-based remote sensing. However, these retrievals are inherently affected by model assumptions, limited angular sampling, and cross-sensitivities to other atmospheric constituents and surface reflectance.

The Hyper-Angular Cloud Polarimeter (HACP) applies the same multi-angular and polarimetric measurement principles, but performs them directly in situ, within natural clouds. This allows for high-resolution, interference-free observation of scattering and polarization properties of cloud ensembles, providing a unique reference for validating and improving satellite retrieval algorithms and enhancing our understanding of liquid and mixed-phase cloud microphysics.

Applications and Advantages

- **Versatile Deployment:** Adaptable to various platforms, including aircraft, mountain top stations, and cloud and aerosol chambers.
- **Non-Intrusive Measurements:** The instrument eliminates the need for traditional sampling, ensuring observations free from sampling artifacts.
- **Cloud Droplet Size Distribution:** Obtain real-time cloud droplet size distribution parameters from the polarization ratio ($-S_{12}/S_{11}$) in the cloud bow region.
- **Real-time Cloud Phase Information:** Receive real-time information on cloud phase (liquid, mixed, ice) through quasi-simultaneous measurements of the linear and circular depolarization ratios S_{22}/S_{11} and S_{44}/S_{11}.
- **Validation of Optical Models for Non-Spherical Particles:** Full phase matrix measurement constraints the optical model used for parameterizations of the particle optics in radiative transfer algorithms.

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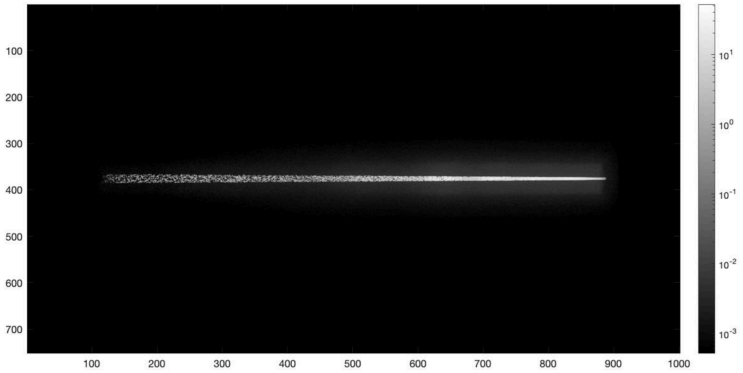
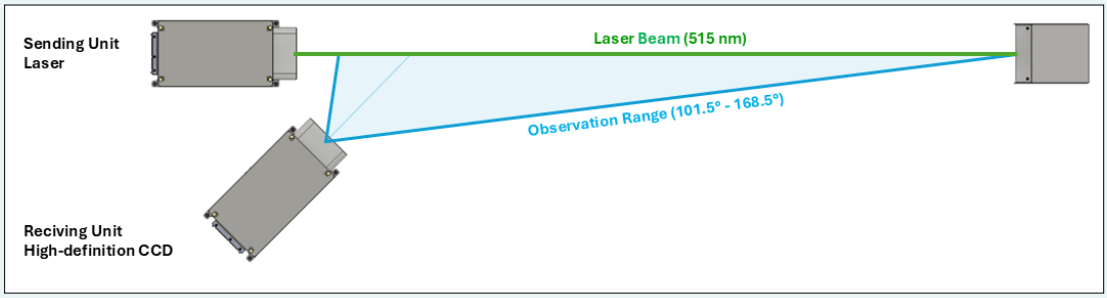
Operation

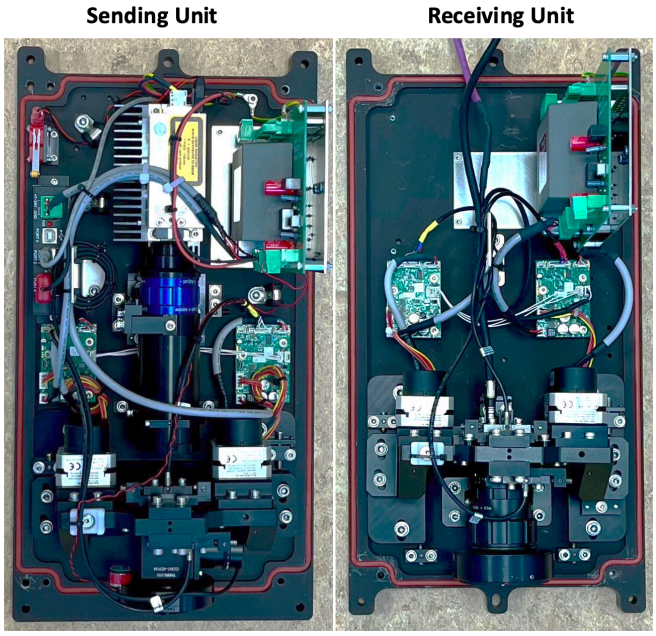
A laser beam with a defined and adjustable polarization state is emitted by the Sending Unit. As the beam interacts with cloud particle ensembles, the Receiving Unit captures the scattered light using a wide-angle lens with a high-definition CMOS sensor. Each pixel on the CMOS corresponds to a specific scattering angle, allowing for the precise measurement of the angular scattering function across a range of 100° to 170°, with an angular resolution better than 0.05°.The scattered light passes through an adjustable polarization filter and a quarter-wave retarder, enabling the measurement of the full scattering phase matrix. This setup allows for comprehensive analysis of the polarization-dependent scattering properties of cloud particles, which are essential for understanding cloud microphysics and validating optical models.



Raw image on the sensor



Schematic diagram of the HACP measurement setup



The HACP units without cover

Setup

Sending Unit

Laser: 25 – 150 mW, 515 nm, cw, TEM_{00} profile. Beam expanded to 12 mm ($1/e^2$) diameter. Polarization state adjustable.

- Laser safety precautions:

✓ Beam divergence adjustable to the on-site safety regulations by adding diverging lens.

✓ Interlock circuit assessable. Lid-switch interlock implemented.

✓ Beam shutter and independent power measurement.

Receiving Unit

- 83.9° wide-angle lens with 8 mm focal length.
- 1.1” CMOS monochrome sensor with 4112 x 3008 pixel resolution, 12 bit depth.
- Thin film linear polarizer and thin film λ/4 retarder sandwich implemented.
- Orientation adjustable via stepper motors.
- Scheimpflug Principle of tilted image plane implemented and adaptable to the actual observation setting.
- Observation volume approximately 200 cm^3 (depending on the actual installation settings).

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HACP Specifications

Concept	The HACP is a cutting-edge laser-based optical instrument designed for precise, non-contact measurement of cloud particle scattering properties to advance atmospheric research and climate modeling.
Angular Resolution	< 0.05°
Observation Range	100° to 170°
Observation Volume	Observation volume approximately 200 cm^3 (depending on the actual installation settings)
Laser	25 – 150 mW, 515 nm, cw, TEM_{00} profile.
Sensor Specifiation	1.1” CMOS monochrome sensor, 4112 × 3008 pixel resolution, 12 bit depth
Temperature	-40 °C to +40 °C (heating system in operation)
Humidity	20 % to 100 % relative humidity (r.h.)
Altitude	< 3500 m asl
IP Protection Rating	IP66: dust-tight and protected against strong water jets
Installation Place	Outside or indoor installation; installation base plates, allowing for flexible adaptation to on-site conditions.

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Discover Next-Generation Cloud Analysis

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