Airborne Multi-angle SpectroPolarimeter Imager (AirMSPI): Polarimetric Calibration, Validation and Aerosol Retrieval Example from the SEAC4RS campaign

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Summary

The Airborne Multi-angle SpectroPolarimeter Imager (AirMSPI) is a pushbroom multi-angle spectroscopic camera with spectral bands near 385, 380, 445, 470, 555, 605, 865, and 935 nm. It is operating on NASA’s high-altitude ER-2 aircraft. Since 2013, AirMSPI uses dual photovoltaic modulator (PVM)-based technology [3] to achieve accurate measurements of the Stokes linear polarization parameters Q and U in the 470, 660, and 865 nm bands. This provides unique observing capabilities for aerosol, cloud, and surface studies. We describe the polarimetric measurement, calibration, and accuracy of the AirMSPI instrument. A well-calibrated Polarization State Generator is used to provide known polarimetric inputs. A high-resolution rotating wire-grid polarizer is used to derive polarimetric calibration coefficients for each pixel, and the results are then validated using partially polarized light generated using tilted glass plates. We also provide an overview of the AirMSPI data collected during the SEAC4RS campaign in collaboration with remote sensing and in-situ data. In addition, preliminary retrieval example of spatially resolved aerosol optical depths (AOD) and single scattering albedo (SSA) are shown in good agreement with reference data from the Aerosol Robotic Network (AERONET).

Instrument Overview

- **Overview**
  - Spectral bands: 385, 380, 445, 470, 555, 605, 865, 935 nm (polarized)
  - Platform: NASA ER-2
  - Flight altitude: 20 km
  - Sampling time: 20 minutes
  - Pixel size: 10 m
  - Observation modes:
    - Scan and stare (ideal for aerosol and surface retrievals)
    - Sweeps (ideal for cloud retrievals)

Polarimetric Measurement

- **Polarized light**
  - Describes the orientation of the electromagnetic wave
  - Contains information on the medium (e.g., atmosphere) it has traveled through
  - Stokes parameters: V_m, Q_m, U_m, and F_m (used to describe the polarization state)

- **Measurements of polarized light (Q, U, and V)**
  - Dual Photovoltaic Modulator (PVM) [2]: measure temporal modulation due to incident polarized light. The temporal filter provides the references and phase allowing to solve for Q, U, and V. The same optics and detector for each pixel (similarly for Q and U) enable retrieval of degree of linear polarization (DOLP) and relative measurements independent of absolute radiometric calibration

Polarimetric Calibration

- **Laboratory calibration to account for optical polarization aberrations**
  - E.g., mirror distortion
  - Cross-talk between Q, G, and U
  - Accounted with high-accuracy Polarization State Generator (PSG)

- **Rotating high extinction polarizer illuminates camera**
  - Provides variable optical angle
    - Polarization alterations before the camera cause linear cross-talks between Q and U
  - A set of 10 calibration coefficients are derived from data
  - Results are validated using partially polarized light generated using tilted glass plates

- **Polarization State Generator (PSG)**
  - Generates DOLP at 0%, 1%, 5%, 10%, 20%, 30%, 40%, 100%
  - Blue: 10% of Earth’s radiation
  - Pre-orientation: variable over 360°
    - DOP uncertainty: >0.005
  - Bandwidth: 350-2150 nm
  - Field of view: 3°

- **Verification of PSG interferometric and phase using an on-board polarization “validator”**

- **Examples of pre- and post-calibration AERONET in DOLP**

Preliminary SEAC4RS Aerosol Retrievals

- **Aerosol Optical Depth (AOD), Single Scattering Albedo, effective index, size distribution, absorptivity, etc.**
  - AOD and SSA maps indicate the potential of AirMSPI to resolve local sources and transport of aerosol AOD agrees with AERONET

- **Cloud-free not yet applied**

References / Acknowledgments

- Felix C. Seidel, David J. Diner, Olga V. Kalashnikova, Feng Xu, Brian E. Rheingans, Michael J. Garay, Russell A. Chipman, Brian J.S. Daugherty, and Ab Davis

We acknowledge the entire AirMSPI and ER-2 teams, Mike Torsa, POHDE, and Brett Hite for establishing and maintaining the DRAGON Baseline/AERONET data.