Airborne Multiangle SpectroPolarimetric Imager (AirMSPI)

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Summary

AirMSPI will be deployed on the NASA ER-2 during SEAC4RS. It is an 8-band (355, 380, 445, 470, 555, 660, 865, 935 nm) pushbroom camera, measuring polarization in the 470, 660, and 865 nm bands, mounted on a gimbal to acquire multiangular observations over a ±67° along-track range. Two principal observing modes are employed: step-and-stare, in which 11 km x 11 km targets are observed at a discrete set of view angles with a spatial resolution of ~10 m; and continuous sweep, in which the camera slews back and forth along the flight track between ±67º to acquire wide area coverage (11 km swath at nadir, target length 108 km) with ~55 m spatial resolution. Step-and-stare provides more angles, but continuous sweep gives greater coverage. Multiple observing modes can be programmed into the instrument and activated under cockpit control. Multiangle radiance and polarization imagery from AirMSPI will (a) provide 3-D scene context where clouds and aerosol plumes are present, plus constraints on radiometric closure, particularly over heterogeneous scenes where 3-D radiative transfer may dominate, and (b) enable retrieval of aerosol and cloud macrophysical properties (distribution, height), microphysical properties (size distribution, single scattering albedo, shape), and optical depth.

Instrument Description

AirMSPI's telescope has an effective focal length of 29 mm and cross-track field of view of ±15º. Filters for spectral band selection are positioned just above the Si-CMOS pushbroom detector array. The filter assembly includes patterned wire-grid polarizers (WGPs) in the polarimetric bands. To obtain high accuracy polarization imagery, AirMSPI employs a retardance modulation system containing dual photoelastic modulators (PEMs). The sampled modulation encodes the Stokes parameters. Both Q (0º-90º polarization) and I (intensity) are obtained from the same pixel [similarly for U (45º-135º polarization) and I], which facilitates the acquisition of high accuracy in $q = Q/I$ and $u = U/I$, from which degree and angle of linear polarization (DOLP, AOLP) are derived. Accuracy is maximized by properly sampling the video signals in synchronization with the dual PEM modulation. AirMSPI's gimbal is driven by an Aerotech actuator and provides images at a programmable set of along-track angles between ±67º. The housing containing the gimbal assembly is mounted in the ER-2 nose (see Fig. 1). A pressure box around the gimbal assembly maintains 4 psi pressure inside the nose compartment, and the sensor head experiences outside ambient pressure (0.7 psi at 20 km altitude). The ER-2 supplies 28 VDC power. Instrument electronics including the flight computer and data acquisition equipment are mounted in a nose rack. Flight control software consists of data acquisition routines, gimbal operation instructions, and a main program. ER-2 attitude and position data are received by a two-channel ARINC-429 board in the AirMSPI on-board computer. Image co-registration and geometric corrections to compensate for aircraft attitude fluctuations are performed in ground data processing (see Fig. 2).

Figure 1. Left: Pressure vessel and cylindrical drum housing the AirMSPI camera. Right: AirMSPI installed in the nose of the ER-2 (visible protruding below the fuselage).

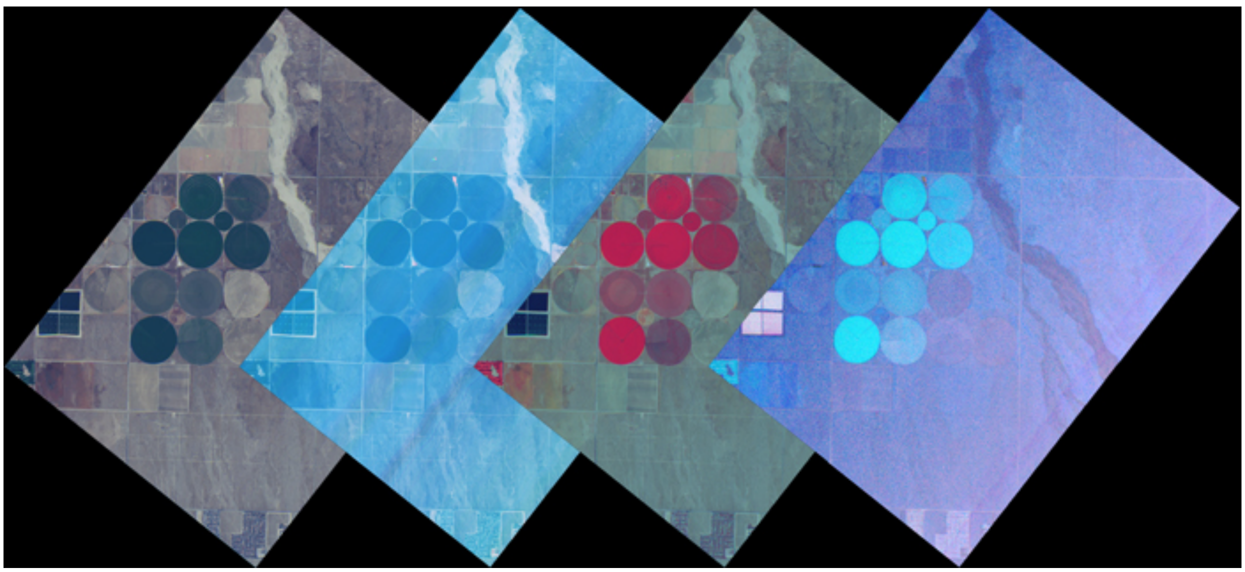

Figure 2. Georectified and map-projected AirMSPI images over Palmdale, CA from October 7, 2010. From left to right, the channels used to make these color composites are: 445, 555, 660 nm intensity; 355, 380, 445 nm intensity; 470, 660, 865 nm intensity; and 470, 660, 865 nm DOLP.

Calibration

The AirMSPI radiometric transfer curve (relationship between illumination and digital output) is established in the laboratory by using a 1.65 m integrating sphere. The sphere also provides the illumination for determining pixel-by-pixel gain coefficients. Independent measurements of the sphere intensity are obtained from a 670-nm photodiode radiance standard calibrated against a NIST traceable incandescent lamp, and a spectrophotometer. Dark offset levels are obtained in flight by recording data when the camera is stowed. Radiometric uncertainty is estimated at 3%. A laboratory polarization state generator (PSG) provides polarimetric calibration. Tiltable plane-parallel glass plates generate partially polarized light and a rotating high-extinction polarizer provides fully polarized light at multiple orientation angles to determine polarization calibration coefficients for each pixel. Uncertainty in degree of linear polarization is estimated to be $<\pm 0.005$. On-board LED-illuminated polarizers enable verifying stability of polarimetric calibration in flight. An optical probe monitors and maintains stability of the PEMs.