Cloud Polarimetry to Reduce Uncertainty in Earth's Radiation Budget

Meredith Kupinski, Assistant Professor, University of Arizona

I am enjoying an inflection point in my career after a decade of experience and resilience as a Research Professor. Advancing the measurement and modelling of polarized light is my expertise. My strengths are evident by my track record of advancing the technology readiness of Earth Science instrumentation and a creative vision for relating prototype measurements to Earth System models, even in the first deployment of new instrument concepts.

The Earth's radiation budget is highly interconnected and accurate models require information from an ensemble of remote sensing platforms. Clouds remain a major source of uncertainty for short- and long-term climate impact. My research will impact Earth System Science by testing novel instrument concepts for their ability to constrain the Earth's radiation budget. Ice clouds have been used as a tuning parameter in Earth System models to account for errors in the radiation at the top of atmosphere and precipitation at the surface. Radiative transfer models predict that thermal polarization signatures are sensitive to microphysical proprieties of thin cirrus ice clouds. However, no existing space platforms measure polarization in this waveband. In only four years, my first Ph.D. graduate Dr. Shanks and I designed, fabricated, and deployed a thermal polarimeter on a high-altitude scientific balloon. In this first-of-its-kind measurement, statistically significant polarization magnitudes of up to 10$\%$ were detected. The relationship between this magnitude and radiance peaked at $\approx$ 270K, confirming the expectation that polarization increases as surface radiation is blocked by clouds of increasing optical thickness. Furthermore, these thin clouds emit slightly polarized thermal radiation with a spectral and angular distribution that depends on their microphysical properties. As the optical depth further increases, the cloud top emission depolarizes due to multiple scattering. The maximum magnitude of our observations exceeds current models of polarized thermal radiation in Earth's atmosphere. Our results have motivated atmospheric scientists to consider more carefully the preferential alignment of ice crystals in radiative models. This doctoral project was selected by the University of Arizona as our institution's nominee for a CGS/ProQuest Distinguished Dissertation Award.

The capability to advance instruments from concept to deployment has inspired ambition among the students I advise. Ms. DeLeon is a Latina PhD student and NSF Research Fellow pursuing ultraviolet polarimetry on unmanned aerial vehicles for wildfire science. As an R1, land-grant, and Hispanic Serving Institution, the University of Arizona offers me compelling opportunities to broaden research participation. To increase the students' awareness of the economic opportunities made possible by their education, entrepreneurship is valued and regularly practiced. Dr. Shanks and I have a provisional patent on the topic of ice and water discrimination using spectrally resolved thermal polarimetry. Advising underrepresented students to achieve high-impact publications, fellowships, professional awards, and intellectual property is a hallmark of my research program.

To explore new inverse problems using commercial off-the-shelf polarization cameras, I am developing the first inverse-rendering pipeline for computer graphics with polarization functionality. This computational tool will utilize my provisional patent on polarimetric importance sampling. I envision combining my strengths in data science and optics to compute nearly real-time (NRT) uncertainty metrics of Earth System data products. This NRT metric will be used to create simple and adaptive acquisition protocols for the instrument concepts we are testing. An NRT uncertainty computation creates an opportunity for prototype instruments that meet science requirements under a wider variety of operational conditions and scene types.