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How can we use ice halos to improve our knowledge about cirroform clouds and the conditions in the upper troposphere?

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University of Minnesota MORRIS
ACE Academic Center for Enrichment Undergraduate Research Opportunities Program
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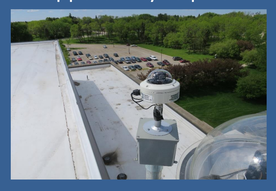
Previous Work in this Project

A cirrus observation program at the University of Minnesota-Morris (UMM) was initiated three years ago. We are collecting and analyzing ice halo appearances as an access to cirrus composition A camera on the roof of the UMM Science building has been observing the sky continuously. Software for image analysis was developed, including algorithms for automatic halo detection, low-cloud removal and the elimination of lens distortion. The halo detection algorithm analyses large series of individual images, and assigns a halo probability based on certain criteria related to the color and brightness distribution in the all-sky images. Our observations so far yield that

- Ice halo appearances are a frequent phenomenon during all seasons.
- Ice halos appear under a wide variety of sky conditions, and with a wide variety of durations, intensities and cloud appearances.
- Not all cirroform clouds lead to halo appearances.

Who we are

- The University of Minnesota-Morris is a small liberal arts college in rural west-central Minnesota.
- The location offers wide horizon views, and seasonal variations in air mass of continental climate.
- The college-owned new Ecostation is a nature reserve that offers opportunity to place an atmospheric observation station.




Undergraduate students with contributions to this project:

- **Stephan Sorenson**, B.A. Physics'14: started image analysis program
- **James Froberg**, B.A. Physics'14: ray-tracing program in MatLab
- **Jieying Jin,** B.A. Mathematics'15: further development of the ray-tracing program
- **Shelby Richard**, B.A. Environmental Science: camera hardware, development of the halo identification algorithm
- **Michelle King**, B.A. Physics and Computer Science'16: halo identification algorithm
- **Morton Greenslit**, B.A. Physics'16: low- cloud identification algorithm
- **Brittney Ferrian**, B.A. Physics'16: development of a Lidar prototype
- **Jamin Stagg**, physics/engineering major '20: scattering behavior of bullet crystals



Plans

Projects:

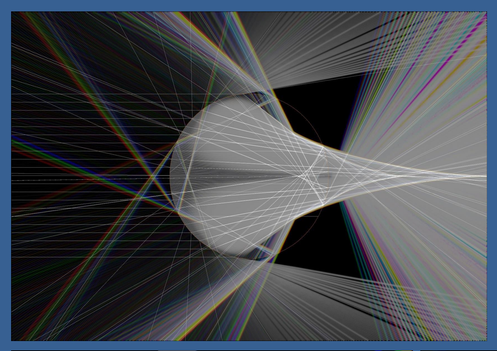
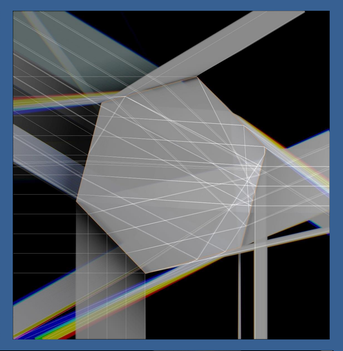
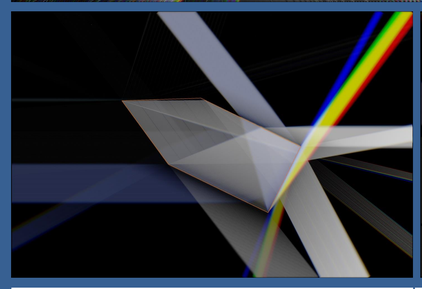
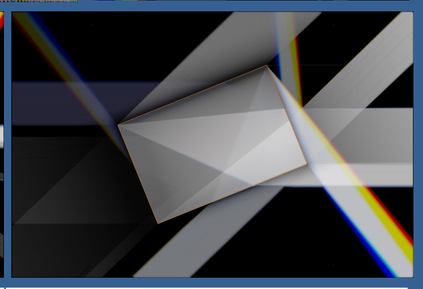
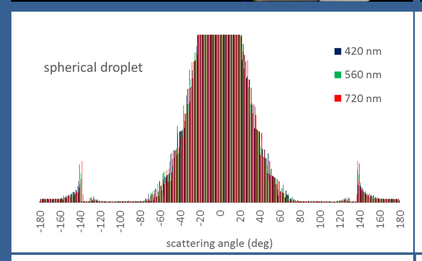
1. A cirrus observation station (COS), together with the control and analysis software, will be constructed for continuous sky observations. The data will be evaluated for the presence of cirrus and ice halos, and the results interpreted for temporal and spatial distribution of cirrus and ice halos, and for the particle size, type and depth distribution of the cirrus clouds.
2. Theoretical groundwork: computer models of scattering behavior of cloud particles

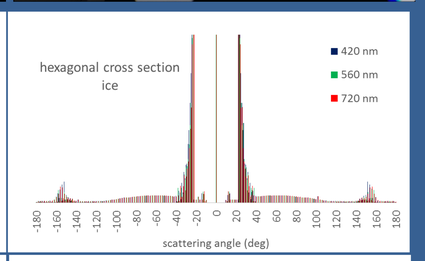
Directions of inquiry:

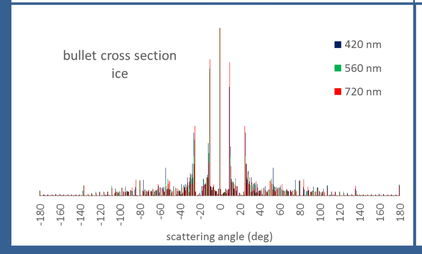
- Analysis of the crystal fraction to improve the radiative treatment of these clouds in GCMs
- Implications of temporal and spatial resolution of halo observations for the evolution of the composition of cirroform clouds in time
- Long-term trends in the distribution of halo appearances, as an indicator of changes in the upper troposphere
- Support for theory development: testing physical models of optical scattering on ice crystals. Progression: ray optics, wave optics, mie scattering

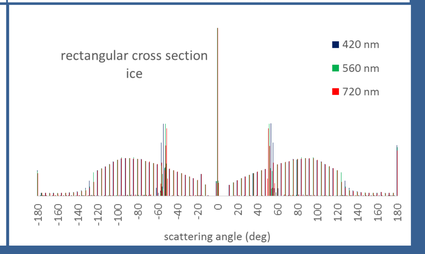
Modeling scattering behavior

We are developing a modeling program to explore the optical scattering behavior of hydrometeors of various shapes. Shown are examples for the 2d ray-tracing investigations. The program is being developed to 3d, and will be expanded to include wave scattering behavior.



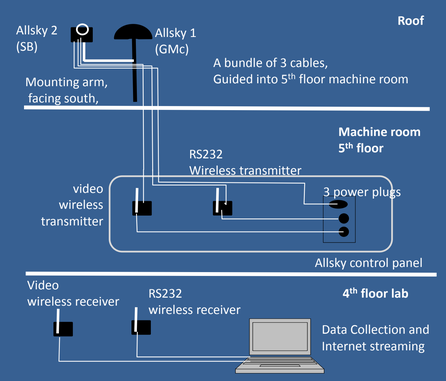




Camera details and image analysis

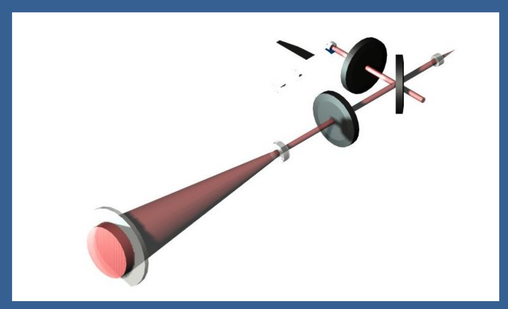
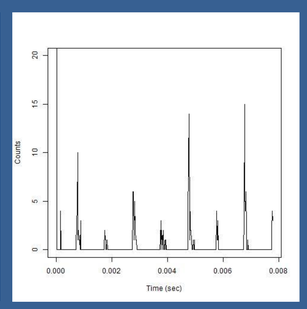
- Orion Starshoot Allsky camera
- On roof of science building since 7-21-2014
- Saves still frames every 30 s (chosen)
- Resolution 480 by 720
- Location (45.589052, -95.902858)
- Replacement: GoPro Hero 4 since June 2017.

Software:
We developed an Image analysis program which assigns a halo probability to each image according to radial brightness distribution around solar position.



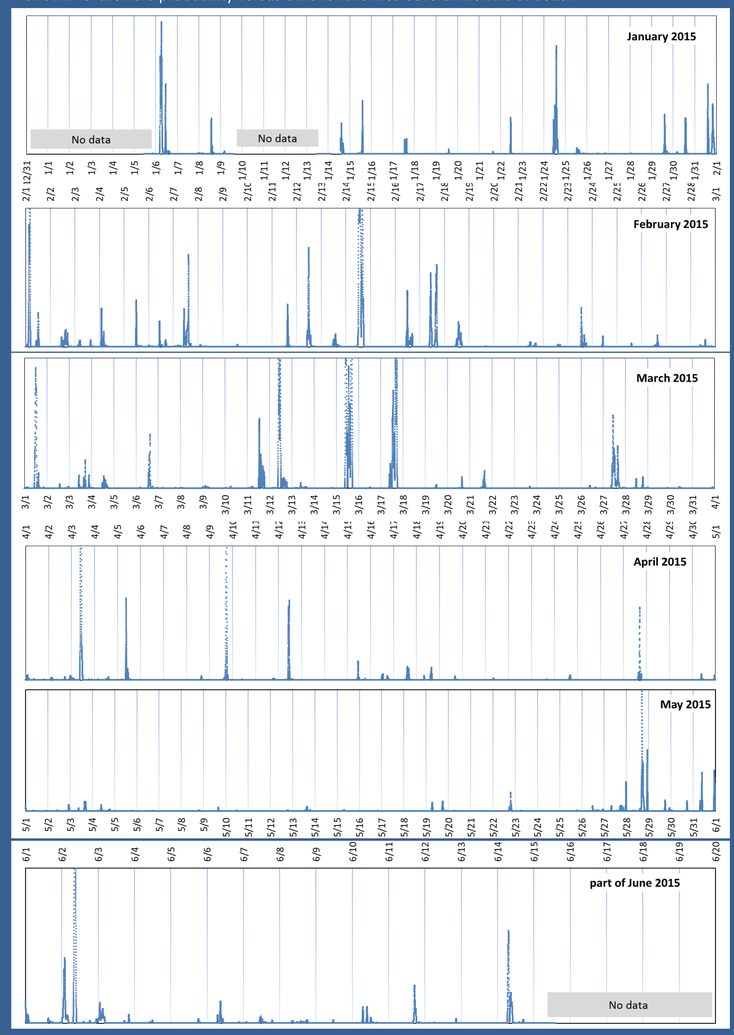
As-designed optical beamline for LIDAR

Laser is OSRAM SPL-LL85 (850nm), time-of-flight using TI TDC7200 time-to-digital converter. Start pulse with laser, up to 5 stop pulses form APD detector. Control using TI MSP430F5529 MCU- new design uses TI MSP432P401R. Data from detector circuit using cw 650 nm diode laser and mechanical chopper. Individual blocks are separate gaps in chopper; two sets come from different start delays.

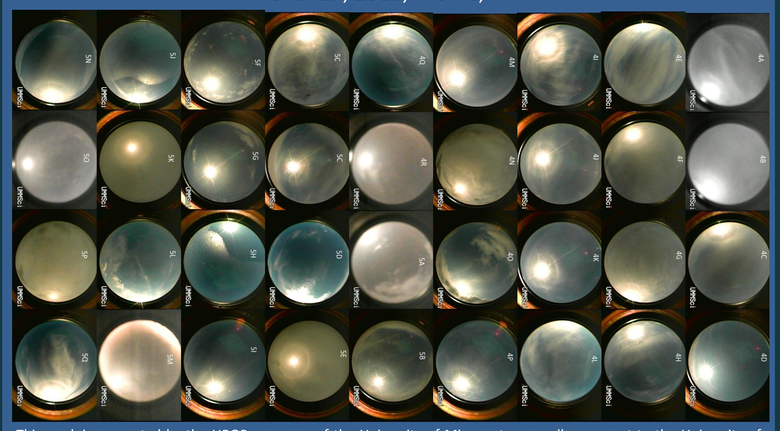



Halo Observations

Shown is the halo probability versus time for the first several months of 2015.



March 17, 2016, Morris, MN



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