COMMUNITY INSTRUMENTS AND FACILITIES (CIF)

CIF Program Introduction

The **Community Instruments and Facilities (CIF)** program consists of state-of-the art instruments and facilities provided by ten US universities. The CIFs listed below are currently supported by the NSF/AGS FARE Program and available for request through the **Facility and Instrumentation Request Process (FIRP)**.

Radars

- CSU Sea-going and Land Deployable Polarimetric Radar (SEA-POL)
- OU Rapid Scan X-band Polarimetric Radar (RaXPol)
- UIUC Flexible Array of Radars and Mesonets (FARM)
- Stony Brook Millimeter-wavelength Radar Facility for Cloud and Precipitation Research (SBRO)

Remote Sensing Suites

- UWi-Madison SSEC Portable Atmospheric Research Center (SPARC)
- UAH Mobile Atmospheric Profiling Network (MAPNet)

Laboratory Facilities

- UU Storm Peak Laboratory (SPL)
- MTU Pi Convection-Cloud Chamber (Pi Chamber)
- NC State Ice Nucleation Cold Stage

Instruments

- Clemson Soot Photometer (SP2)

Many of the facilities are mobile and can travel to different locations for scientific research as well as hands-on education and outreach activities.

CIF Overview

CSU SEA-POL

The **Colorado State University Sea-Going and Land Deployable Polarimetric Radar** is a transportable, C-band, dual-polarization precipitation radar that can be used for a wide range of maritime or land-based science research.

OU RaXPol

The **University of Oklahoma Rapid Scan X-band Polarimetric Radar** is a truck-mounted, mobile radar that provides high-temporal resolution measurements essential to understanding processes leading to the formation and evolution of severe weather.

UIUC FARM

The **University of Illinois Flexible Array of Radars and Mesonets** comprises multiple dual-polarization, dual-frequency Doppler on Wheels radars, mobile mesonets, sounding systems, disdrometers, and pods used to advance understanding of a wide range of meteorological phenomena.

SBRO

The **Stony Brook Millimeter-Wavelength Radar Facility for Cloud and Precipitation Research** features several mm wavelength radars including the 35 GHz KASPR and 94 GHz ROGER radars and an extensive suite of auxiliary instruments for studying a range of dynamical and microphysical cloud processes.

UW SPARC

The **University of Wisconsin Madison Space Science and Engineering Center Portable Atmospheric Research Center (SPARC)** consists of a specialized suite of atmospheric observing instrumentation housed in a mobile research laboratory that can be rapidly deployed to regions of interest for atmospheric science research.

UAH MAPNet

The **University of Alabama - Huntsville Mobile Atmospheric Profiling Network** consists of a diverse set of instruments to study boundary layer and precipitation processes. Three profiling systems and an X-band dual polarization radar are designed for mobile operations and experimental design flexibility.

UU SPL

The **University of Utah Storm Peak Laboratory** is a high-elevation, mid-continental, atmospheric research station located in Colorado. The Laboratory serves as a national resource to advance research and research training in high elevation atmospheric science.

MTU Pi Chamber

The **Michigan Technological University Pi Convection-Cloud Chamber** along with an extensive set of auxiliary instrumentation simulates cloud conditions within the range of pressures and temperatures that occur in the troposphere. The chamber enables measurements of thermo-dynamics, turbulence, aerosol, and cloud properties.

NC State CS

The **North Carolina State Ice Nucleation Cold Stage** is suitable for studying ambient ice nucleating particle concentrations and laboratory-based, process-level studies of the nucleation process.

CLEMSON SP2

The Clemson University Single-Particle Soot Photometer is available for laboratory studies, airborne field studies, and ground-based field deployments to study the concentrations and sizes of airborne black carbon.

CSU SEA-POL

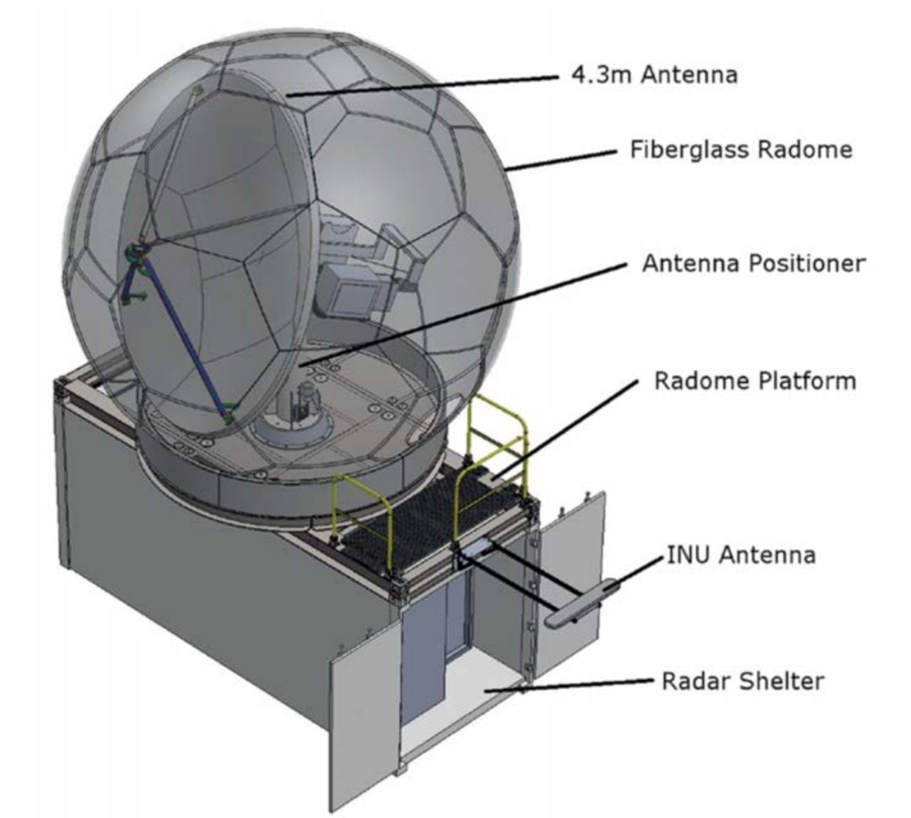
The **Colorado State University Sea-Going and Land Deployable Polarimetric radar (SEA-POL)** is a C-band, dual-polarization radar, and the only advanced technology, community-requestable, sea-going precipitation radar facility. It can be used to address a wide range of maritime or land-based science research, including advances in tropical and mid-latitude weather, regional climate and climate change, cloud microphysics, dynamics of convective storms, and extreme weather impacts. SEA-POL can also contribute to interdisciplinary science in oceanography, hydrology, and water resources.

The radar is designed to be portable and rugged, both mechanically and electrically. Therefore the radar is capable of operating in harsh environments. The radar can be deployed on ships and at remote field sites around the world. It offers platform stabilization for oceanic environments while still having high-quality polarimetric capabilities for all-purpose use.

The radar is based in Greeley, CO.

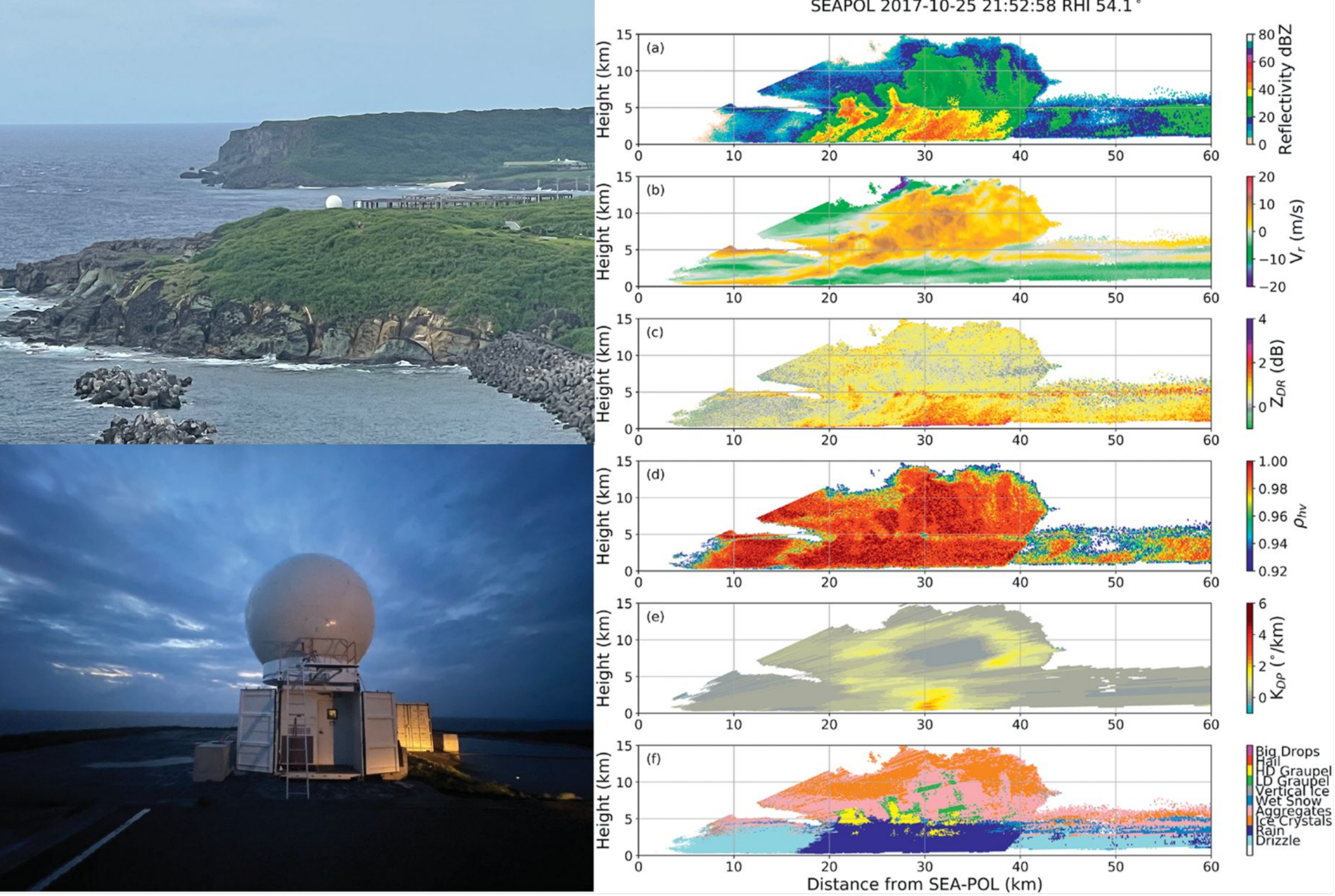
Features:

- 250 kW Magnetron transmitter, low-maintenance solid-state modulator
- Rugged design with radome able to withstand high winds and harsh environments
- Dynamic platform stabilization using internal navigation system for shipborne deployments
- 1° beamwidth antenna
- Containerized system that is transportable worldwide
- State of the art polarimetric signal processor
- Remotely operable
- Frequency agility to avoid interference



SEA-POL SPECIFICATIONS

The CSU SEA-POL radar measures dual-polarization data over a range in excess of 200 km. The radar operates at C-band (5.65 GHz, 5-cm wavelength) and has a 4.3 m stabilized antenna system. An inertial navigation unit measures ship motion and sends compensation commands to the antenna positioner. Doppler velocity data is also corrected for ship velocity. By correcting for ship roll and pitch, high quality polarimetric data is maintained over a large range of sea states. The radar operates in simultaneous transmit and receive mode, as well as horizontal-only mode, with a sensitivity of -7 dBZ at 100 km. The radome is designed to handle wind loads up to 115 mph. A variety of pulse widths, pulse repetition frequencies, and scanning strategies are supported. The radar is packaged in three ISO-668 1C containers for transportability and ease of deployment.



Above: (Left) Photos of SEA-POL on Yonaguni island, Japan during PRECIP 2022. (Right) Range–height indicator (RHI) data from SPURS-2 shipborne deployment of (a) reflectivity, (b) Doppler radial velocity corrected for storm motion, (c) differential reflectivity, (d) copolar correlation coefficient, (e) specific differential phase, and (f) dominant hydrometeor class at 2152:58 UTC 25 Oct 2017 (Rutledge et al. 2019)

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OU RaXPol

The **University of Oklahoma Rapid Scan X-band Polarimetric Radar (RaXPol)** is a truck-mounted, rapid-scan, highly flexible, dual-polarization radar that provides observations needed for the study of high impact and fast evolving events such as tornadogenesis, deep convection and electrification, post-wildfire hydrology and flash floods, lake-effect and orographic snowstorms, and tropical cyclones.

This mobile radar also serves as an excellent educational and outreach tool, providing opportunities for students to interact with state-of-the-art instrumentation.

RaXPol is maintained by the Advanced Radar Research Center (ARRC) at the University of Oklahoma (OU), which has long-standing experience in design and operation of complex radar systems.

RaXPol provides rapid updates of direct and reliable dual-polarization weather observations, which are much needed for the study of high impact and fast evolving weather events. It can be rapidly deployed with real-time data transmission capabilities and offers flexibility in scanning strategies to focus observations on areas of interest at high spatio-temporal resolution. The mobile RaXPol facility can travel to different locations for scientific exploration and research which allows diverse institutions and underrepresented groups to engage in learning experience with hands-on activities.

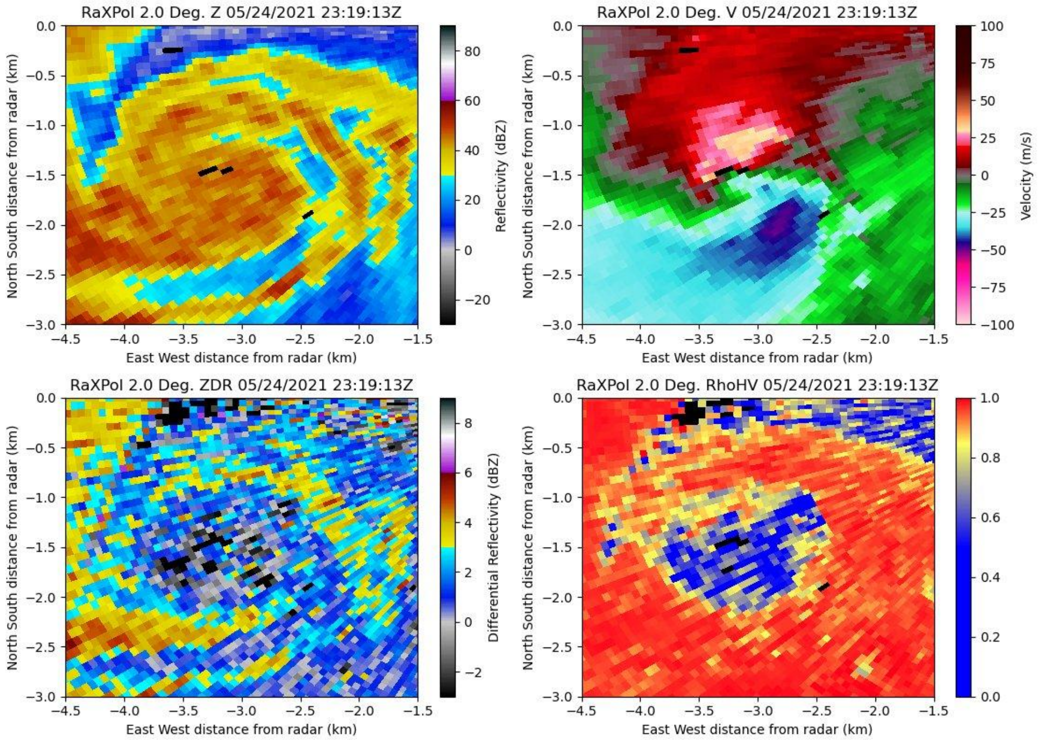
RaXPol Specification	
Transmitter	
Frequency	9.73±0.02 GHz
Peak Power	20 kW (TWT)
Pulse Width	0.1 – 40 μs
waveforms	Frequency Hopping, LFM/NLFM
Polarization	Dual-linear (STAR)
PRT	Uniform or staggered
Antenna	
Diameter	2.4 m
Beamwidth	1.0°
Gain	44.5 dB
Scan Rate	180° s^{-1} in az 36° s^{-1} in el
Products	$Z, v, \sigma_v, Z_{DR}, \rho_{HV}, \phi_{DP}$

System Overview

RaXPol boasts extremely rapid pedestal speeds, which enable a volume scan to be completed in as little as 20 seconds. The truck-based platform can quickly maneuver to a target area, deploy, operate, and depart with minimal preparation. While these advantages make RaXPol well-adapted to observation of severe weather phenomena, the arbitrary transmit waveform and raw I/Q data recording capabilities also allow for experiments with pulse compression and innovative radar signal processing.

RaXPol addresses a well-established scientific community priority to have a community-accessible radar that provides high-temporal resolution measurements (< 1 min). Such rapid-scan data are essential to understanding processes leading to the formation and evolution of severe weather and capturing fine-scale microphysical and dynamic processes.

The truck-mounted RaXPol radar offers an agile experimental platform to create highly customized radar experiments for research and education. OU's team of scientists and engineers are deeply experienced in conducting radar field experiments around the world and can assist with field experiment planning, in-field coordination, and post-deployment data quality control, curation, and analysis.



Research

RaXPol is well-suited to studying severe weather hazards such as tornadoes, hail, hurricanes, and damaging windstorms. As part of the CIF, NSF users can formally request RaXPol to study severe weather throughout the United States and worldwide. In addition to severe weather research, significant scientific potential exists in deep convection and precipitation in turbulent environments with rapid-scan systems to capture elusive microphysical and dynamic processes that are not observed with 2 – 3 min volume scans of existing mobile radars. Transformative research opportunities exist to better understand the evolution of deep convection, storm electrification, winter storms, flash floods, and wildfires using RaXPol. Such high spatio-temporal data could also push the limits of data assimilation schemes and provide critical observations to improve numerical models.

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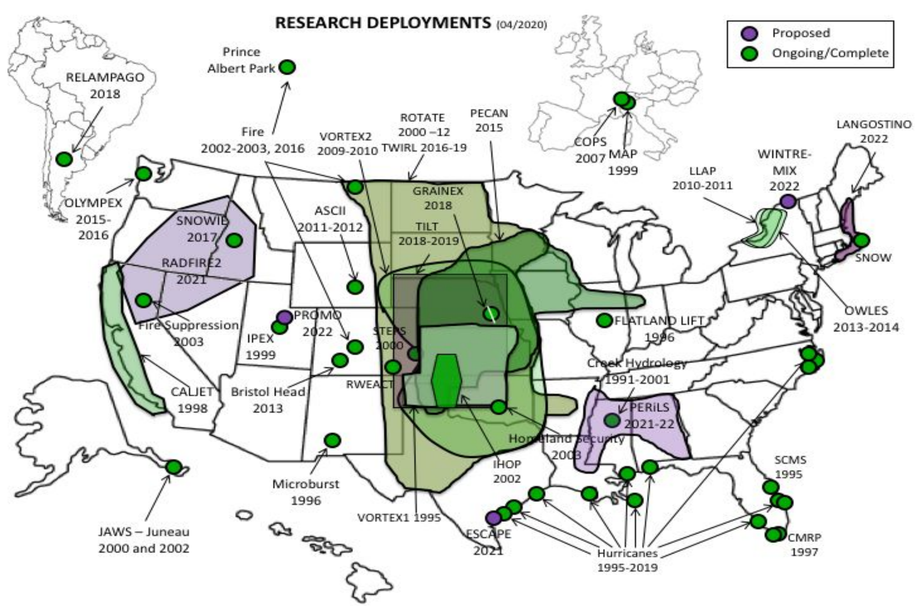
Request Form:
https://arrc.ou.edu/cif.html

UIUC FARM

The **University of Illinois Flexible Array of Radars and Mesonets (FARM)** uniquely combines a network of radars with a comprehensive network of in-situ observation systems. The network includes four mobile radars, an array of mobile mesonets, quickly deployable weather stations (pods) and pole-mounted instruments, upper air and swarm sounding systems and disdrometers. FARM is the only configurable, multiple Doppler, dual-polarization, multiple frequency, mobile radar network available to the NSF observational community.

FARM instrumentation has uniquely broad applicability to winter, tropical, alpine, orographic, and severe mesoscale studies. FARM has been used as core instrumentation in dozens of field programs, resulting in hundreds of publications. FARM instrumentation including the Doppler on Wheels (DOWs) and C-band DOW (COW) are student operable and extremely well-suited for educational use. The FARM observational capabilities bring nearly 30 years of experience, common instrument maintenance and operation protocols, and data quality control protocols to maximize instrument reliability in the field, calibrations, and production of the highest quality data.

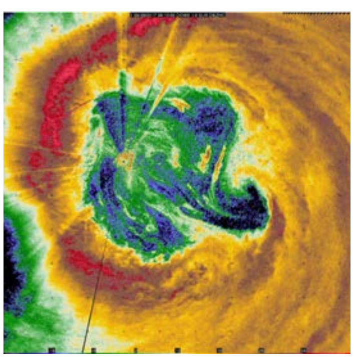
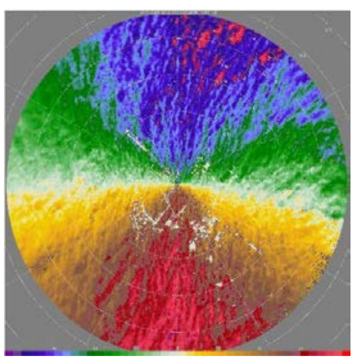
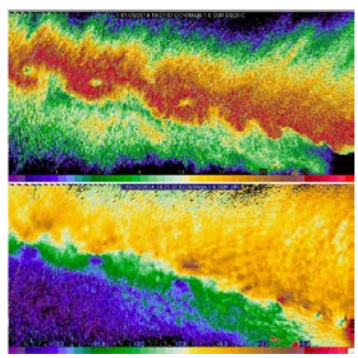
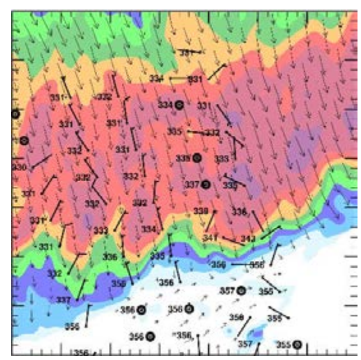


DOWNET (Dual-Frequency, Dual-Polarization, Dual-Doppler)

Transmits: 2 x 250 kW dual-Pol 2 x 45 deg or H & V separately	Beamwidth: 0.93 deg	Scan rate: 50 deg/sec
Gating: 12.5 - 150 m (very small)	Pulsing to 6,000 Hz Staggered Nyquist > 100 m/s	Processing: TITAN Simultaneous stagger with Dual-Pol processing: LDR, V, Z, Rho-HV, ZDR, Phi-DP Two independent frequencies Full time series recording



DOWNET, comprising DOW6 and DOW7, is the only dual-polarization, mobile/targetable network, employing narrow-beam and dual- frequency radars. DOWNET, and DOW6 or DOW7 individually, or in combination with COW and other FARM instrumentation, are used in a range of atmospheric studies including alpine, winter, agricultural, mesoscale, tropical, and purely education missions. Dual-frequency, dual-polarization allows either double-fast scanning or simultaneous collection of LDR, rho-HV, and phi-DP.

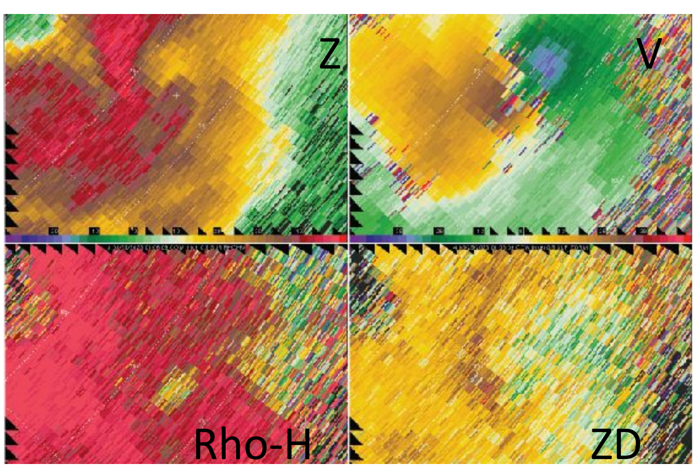





Images display DOWNET deployments in alpine environments, observing wildfires, and a tornado. Data (clockwise) show hurricane eye, hurricane boundary layer, and snowband microvortices; and Dual-Doppler integrated with FARM in-situ measurements.

COW (C-band on Wheels)

Transmits: 2 x 1 MW dual-Pol 2 x 45 deg or H & V separately	Beamwidth: 1 deg	Scan rate: 35 deg/sec
Gating: 12.5 - 150 m (very small)	Pulsing to 6,000 Hz Staggered Nyquist > 100 m/s	Processing: TITAN Simultaneous stagger with Dual-Pol processing: LDR, V, Z, Rho-HV, ZDR, Phi-DP Two independent frequencies Full time series recording

COW is the only narrow-beam (1 deg) C-band, dual polarization, dual frequency mobile targetable radar. Unique among narrow-band C-bands, COW can be set up in 2 hours, permitting redeployment for every IOP. COW individually, or in combination with DOWNET and CROW and other FARM instrumentation, is most useful when full chasing-mode DOWs are needed. COW can be an anchoring radar to a chasing DOW network or pair with stationary radars. COW can be used in a range of atmospheric studies including alpine, winter, agricultural, mesoscale, tropical, and purely education missions. Dual-frequency, dual-polarization allows either double-fast scanning or simultaneous collection of LDR, rho-HV, and phi-DP.



V R

Distant tornado circulation (approx. 50 km) resolved with 1 deg beam.

CROW (Configurable Radar on Wheels)

RSDOW is narrowest-beam rapid scan targetable mobile radar. RSDOW's 0.8 x 0.9 deg beams permit the sharpest spatial data. Six simultaneous beams, canned at 50 deg/sec, produce 7 s volumetric data. Sub-1 deg beams combined with 7 second volumes produce the best match of fine spatial and temporal observations of any radar.

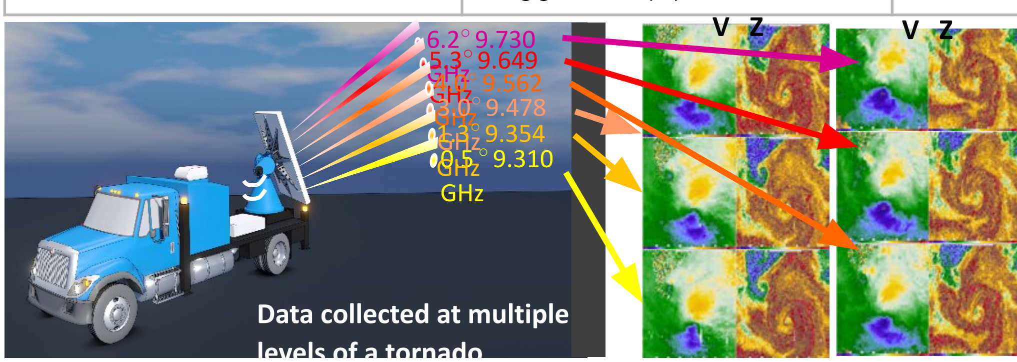
Transmits: 45 kW Single Pol	Beamwidth: 0.8 x 0.9 deg	Scan rate: 6 x 50 deg/sec for 7 s volumes
Gating: 11 - 150 m	Pulsing up to 6,000 Hz Staggered Nyquist > 100 m/s	Processing: TITAN V, Z, SW

Mini-COW is the most powerful and fastest scanning mobile C-band dual-polarization radar. Mini-COW employs a 1 MW transmitter, powerful modern processing, staggered-PRT simultaneous with dual-polarization. Mini-COW is excellently suited when deep penetration into intensive precipitation is needed and therefore ideal for MCS, QLCS, Supercell, and Hurricane observations.

Transmits: 1 MW Dual-Pol	Beamwidth: 1.5 deg	Scan rate: 50 deg/sec
Gating: 12.5 - 150 m	Pulsing up to 6,000 Hz Staggered Nyquist > 100 m/s	Processing: TITAN Simultaneous stagger with Dual-Pol processing: V, Z, rho-HV, Phi-DP Full time series recording

DOW8 is a 1-deg beam single-polarization, single-frequency mobile radar. DOW8 is best suited for multiple Doppler studies, as a nimble extra targetable radar to extend multiple Doppler networks, in a variety of precipitating and clear air meteorology.

Transmits: 100 kW Single Pol	Beamwidth: 10.93deg	Scan rate: 35 deg/sec
Gating: 12.5 - 150 m	Pulsing: up to 6,000 Hz Staggered Nyquist > 160 m/s	Processing: TITAN V, Z, SW



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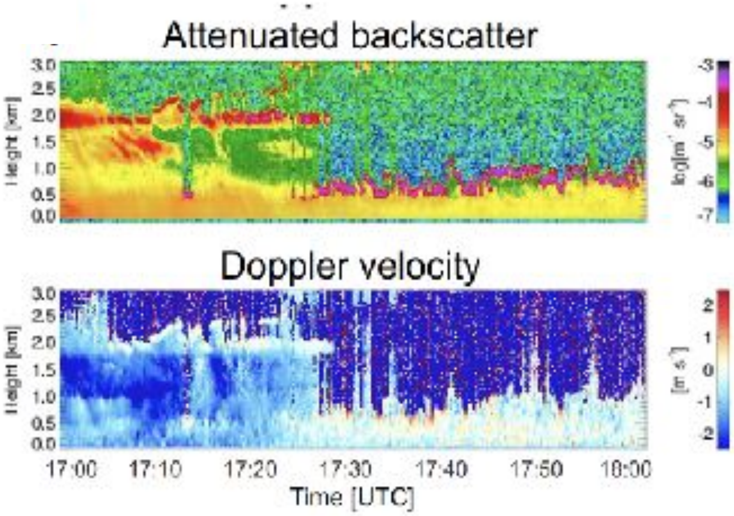
Observatory overview

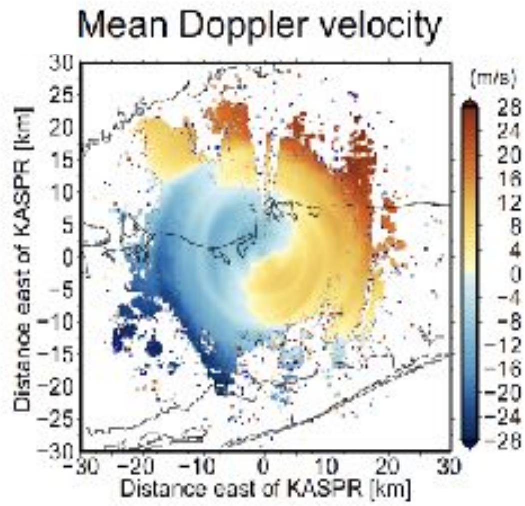
SBRO

The State University of New York at Stony Brook Millimeter-wavelength Radar Facility for Cloud and Precipitation Research includes a state-of-the-art 35 GHz (Ka-band, 8-mm wavelength) Scanning Polarimetric Radar (KASPR), a 94 GHz (W-band, 3.2-mm wavelength) profiling radar (ROGER), a 24 GHz (Ku-band, 1.25-cm wavelength) Micro-Rain Radar (MRR-PRO) and a supporting set of modern auxiliary instruments including a long range Vaisala backscatter lidar, a Parsivel2 disdrometer, a Pluvio weighting gauge, a surface camera, and a weather station. The facility is container based and transportable.

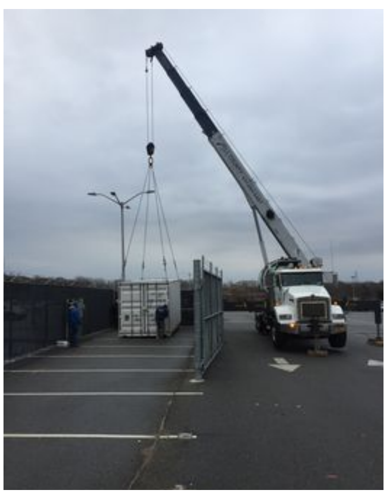
This comprehensive millimeter- wavelength cloud radar facility can provide measurements in a wide spectrum of cloud and precipitation conditions from coastal fog to winter storms. The facility is complementary to other airborne and surface-based community observing facilities and is suitable for both land and ship-based deployments.

The facility enables the study of cloud systems critical to climate applications such as boundary layer clouds, convective anvils, mid-latitude cirrus, and mixed-phase stratiform clouds. It will provide unique, high spatiotemporal resolution microphysical and dynamical observations that are needed for investigation of the role of meteorology and aerosol in altering cloud and precipitation systems using a combination of observational and modeling analyses. The facility provides foundational training in observational research and operation of remote sensing facility to the next generation of atmospheric scientists.





Left: Example of boundary layer observations from the Doppler lidar (aerosol and hydrometeor backscatter (top) and Doppler velocity (bottom)
Right: Example of horizontal radial Doppler velocities.



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Request Form:
https://docs.google.com/forms/d/e/1FAIpQLSfwZJeHe4EOQfaJJwJijZLmmwiJxo6eqPidoNV21zVxaXmIOA/viewform

UW-Madison SPARC

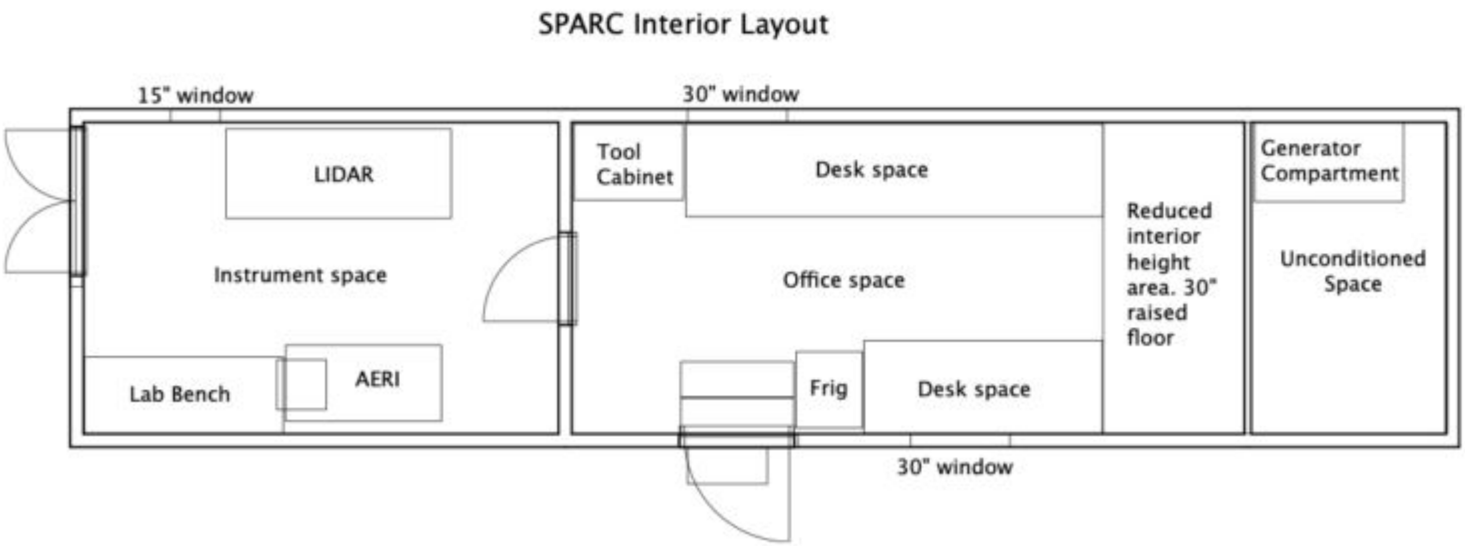
The **University of Wisconsin-Madison Space Science and Engineering Center Portable Atmospheric Research Center (SPARC)** is a 11-m (35-ft) towable trailer, designed to support innovative research with a state-of-the-art specialized suite of atmospheric observing instrumentation housed in a mobile research laboratory that can be rapidly deployed to regions of interest for atmospheric science research.

SPARC provides capability to measure properties of the lowest levels of the Earth's atmosphere that impact people and is critical for testing and improving models for weather forecasting, air quality, and climate change.

The SPARC observation suite consists of three core profiling ground-based remote sensing instruments, augmented by in-situ meteorological sensors.

- The **Atmospheric Emitted Radiance Interferometer (AERI)** is a hyperspectral sounder that measures downwelling infrared radiance with high absolute accuracy. The broad spectral content and spectral resolution allow retrievals of vertical profiles of temperature and water vapor, as well as trace gases, and downwelling infrared spectral signatures of clouds and aerosols.
- The **High Spectral Resolution Lidar (HSRL)** measures absolutely calibrated vertically resolved backscatter and extinction cross-sections. These observations provide detailed cloud and aerosol profiles with sensitivity to the entire atmospheric column, including cirrus and stratospheric aerosols.
- The **Doppler Lidar** (Halo Photonics Stream Line XR) provides vertical wind profiles.
- In-situ **MET Sensors** include Vaisala RS-41 radiosonde launches for atmospheric profiling, and probes for measuring surface temperature, humidity, pressure, and winds.

The highly specialized ground-based remote sensing instruments provide simultaneous thermodynamic and kinematic profiles in the planetary boundary layer, along with detailed profiles of cloud and aerosol properties of the entire atmosphere at high temporal and vertical resolution. These observations can enable new field experiments to test models of physical processes in the boundary layer, and to fill spatial and temporal gaps in current observing systems that have prevented scientific advancement.

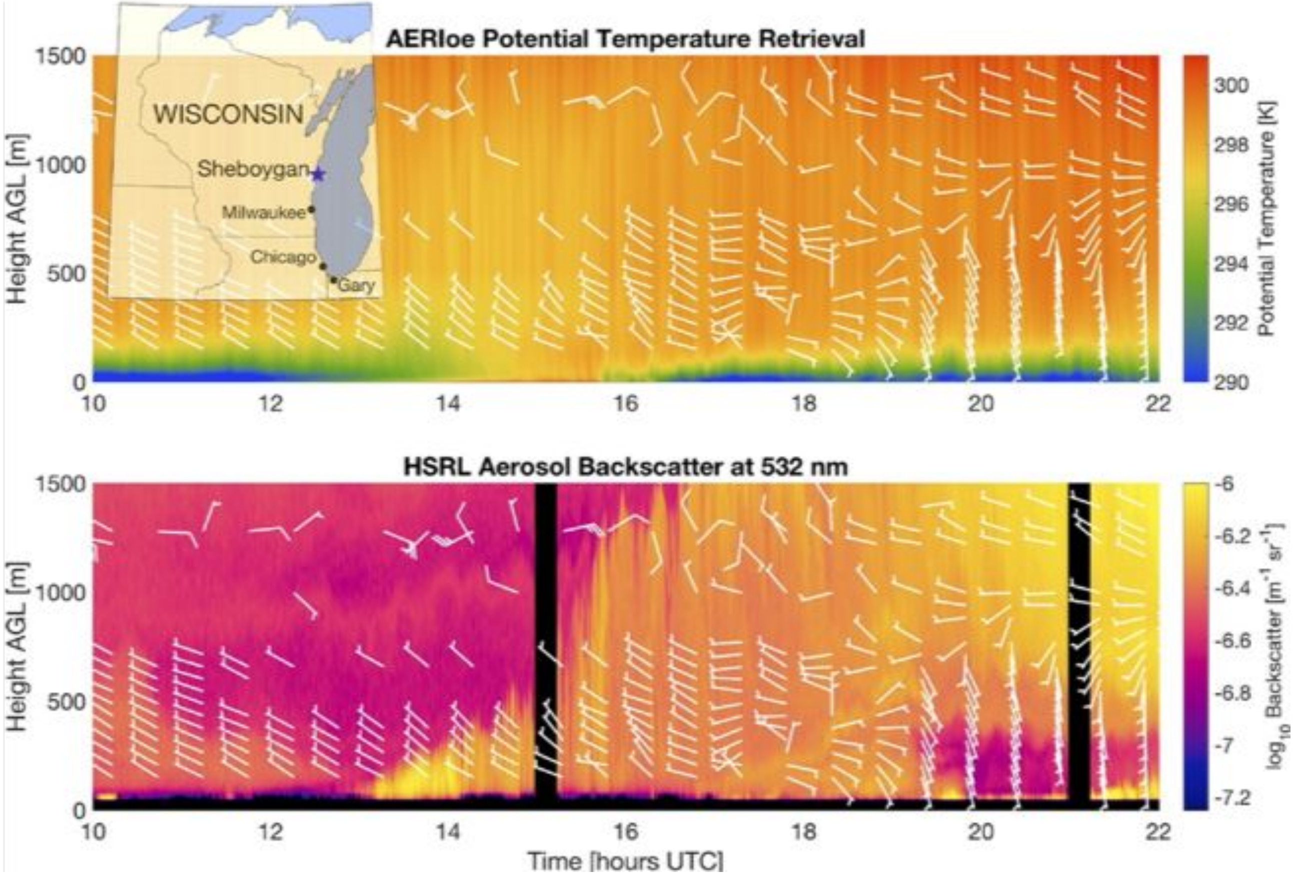


The SPARC is a custom-designed trailer, towed by a Ford F-550 pickup truck equipped with a fifth wheel trailer hitch. The interior has two rooms: an instrument room for the core remote sensors, and an office workspace equipped with desks, toolboxes, multiple screens for monitoring the status of the instruments, and a small galley; a team of four researchers can work in a well-conditioned and quiet environment.

Internal wired ethernet connects the instruments, processing systems, on-board data archive, and workstations; Wi-Fi access is also available. An external wired or wireless internet connection enables regular data transfers and remote monitoring of all critical systems.

Electrical power can be provided either through direct connection to an external 125/250V power supply of up to 60-A, or through an on-board propane-powered generator. The onboard liquid propane (LP) tank capacity is sufficient to operate all SPARC instruments and systems for approximately 24 hours. Large external propane tanks can be rented to support continuous SPARC operations at remote locations for periods of months. A battery backup system can power the SPARC for approximately one hour.

The SPARC can transition from being in transit to full deployment in approximately 30 minutes with two personnel, which makes it suitable for temporary deployment in the path of transient phenomena such as severe weather. It is also capable of long-term stationary operations for indefinite periods of time to capture longer-lived or regularly occurring events. The trailer walls have added insulation to facilitate operations in both very hot and cold environments.



The above graphics demonstrate the SPARC Instruments working in concert to monitor a lake breeze event on the eastern shore of Lake Michigan, showing the structure of the boundary layer and the advection of pollution. Together, these instruments show a comprehensive picture of the evolution of the atmosphere.

SPARClet

A sister enclosure option was developed, called the SPARClet, that provides additional deployment options for the HSRL, and in the future for the AERI. The SPARClet is a highly customized sea container, fully temperature controlled and power conditioned, requiring only a source of shore power for autonomous operation. It can be shipped by flatbed truck, ship or plane. It is particularly well-suited for international deployments, marine deployments and other challenging environments.

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Request Form:
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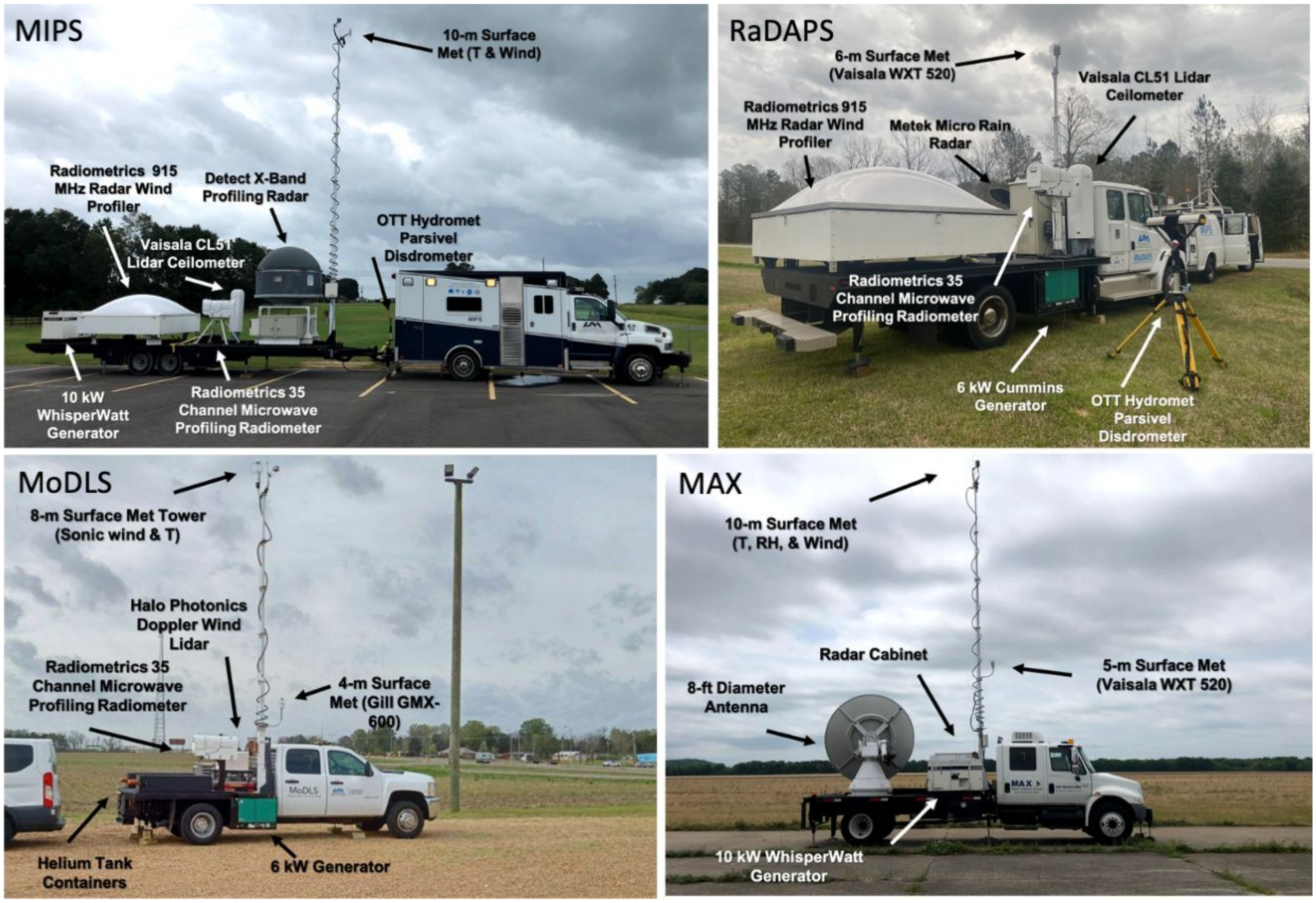
UAH MAPNet

The **University of Alabama in Huntsville Mobile Atmospheric Profiling Network (MAPNet)** consists of four mobile platforms, each with a suite of instruments that specialize in remotely retrieving temperature, moisture, wind, and other properties, ranging from precipitating systems to the fair-weather atmospheric boundary layer. MAPNet has been used to study a variety of topics, including boundary layer processes, severe thunderstorms and their rapidly-evolving environments, landfalling hurricanes, and winter weather.

MAPNet consists of the

- **Mobile Integrated Profiling System (MIPS)**
- **Rapidly Deployable Atmospheric Profiling System (RaDAPS)**
- **Mobile Doppler Lidar and Sounding system (MoDLS)**
- **Mobile Alabama X-band radar (MAX)**

Collectively, the MAPNet instruments include two 915 MHz radar wind profilers, three microwave profiling radiometers, three lidar ceilometers, an X-band profiling radar, a micro-rain radar, a Doppler lidar, three balloon sounding systems, a scanning X-band dual polarization radar, and surface instrumentation, including sonic anemometers for high resolution measurements and turbulent flux estimates. These instruments provide temporal resolution of 1-300 s and varying vertical resolution (15-100 m).



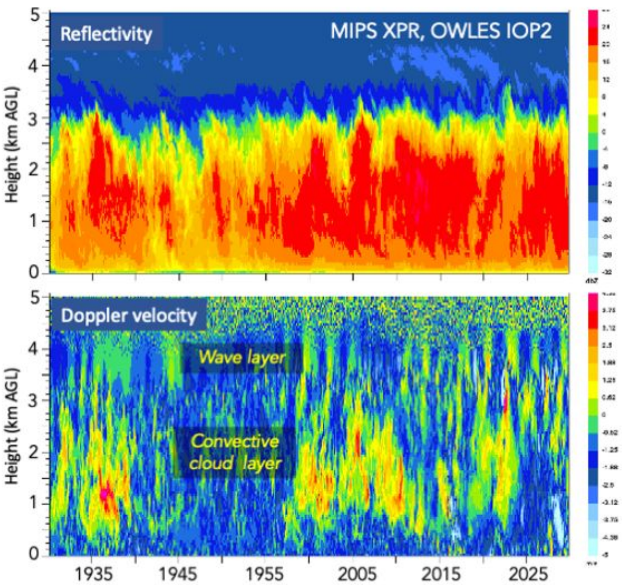
The combination of radar wind profilers, lidars, microwave radiometers, and other instruments can be integrated to provide high-resolution profiles of wind, temperature, humidity, aerosols, cloud base, and precipitation from the atmospheric boundary layer (BL) to middle tropospheric heights, over a broad range of fair to inclement weather conditions.

The UAH profiling facilities have been used over the past 25 years in field campaigns addressing a variety of topics such as air quality, convective initiation, bores and internal gravity waves, severe weather, tropical cyclones, and winter storms. New and current areas of science where the MAPNet instruments are useful include impacts of surface heterogeneities on the ABL, temporal transitions in the ABL fog, cloud electrification/lightning studies, and investigations of biological flyers.

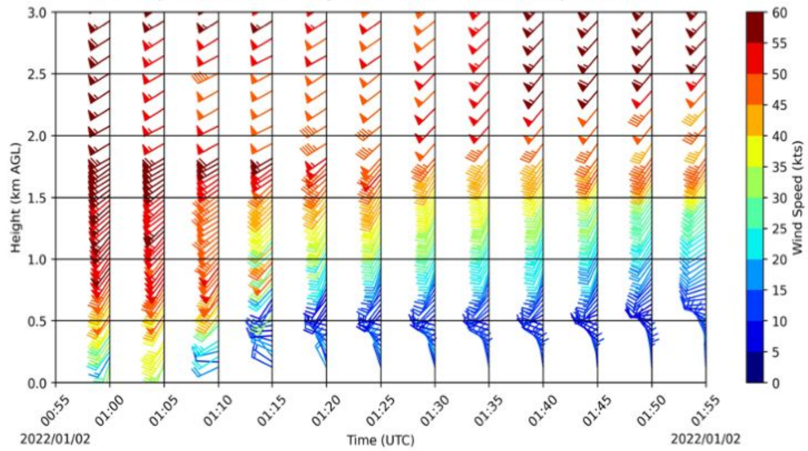
MAPNet
MIPS MAX RaDAPS MoDLS
Mobile Atmospheric Profiling Network

MAPNet example measurements

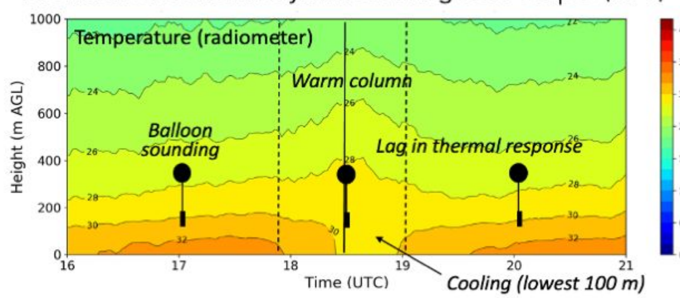
Fine-scale structure in a lake-effect snowband



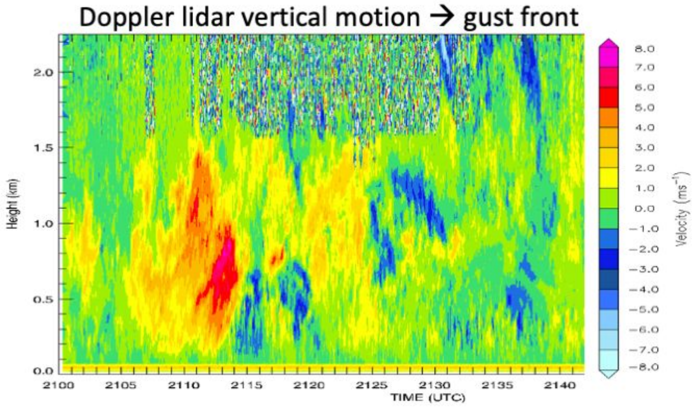
Passage of a boundary over MIPS (tornadogenesis)



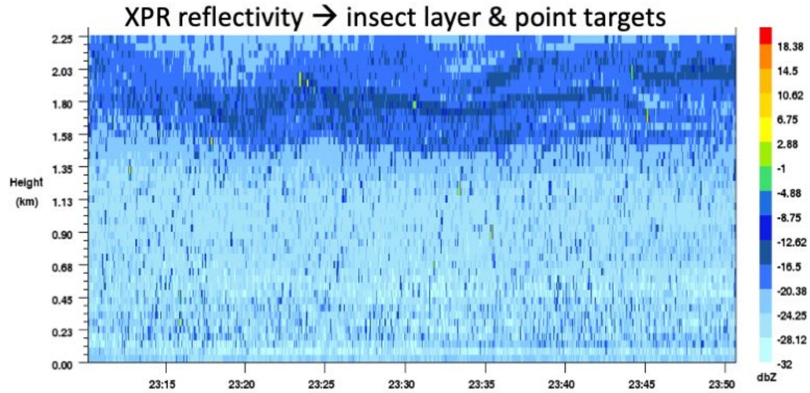
Evolution of BL thermodynamics during 2017 eclipse (MPR)



Doppler lidar vertical motion → gust front



XPR reflectivity → insect layer & point targets



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Request Form:
https://www.nsstc.uah.edu/mapnet/request/index.php

UU SPL

The **University of Utah Storm Peak Laboratory** is a unique, cutting-edge, permanent mountain-top research station located in the Rocky Mountains of northwestern Colorado. Although SPL has been in existence in various forms for more than 40 years, the facility is the latest stage of an evolutionary process of providing a practical, easily accessible facility for researchers, teachers, and students of all ages and abilities.

SPL is situated on a 70 km long north-south mountain barrier, oriented generally perpendicular to the prevailing westerly winds. SPL is approximately 1150 m above, and to the east of the agricultural Yampa Valley, and the town of Steamboat Springs, CO. Located on a peak with limited upwind vegetation or topography to create local turbulence under normal airflow conditions, SPL is ideally situated for in-cloud measurements. This exposure also frequently allows clear-air physical and chemical measurements of the free troposphere (at approximately the 700 mb level) uncontaminated by the local boundary layer.

Instruments available at SPL provide valuable measurements for research focused on aerosol chemical and physical properties; cloud and snow microphysics; atmospheric transformation and transport of mercury; and detection of long-range transported dust and regional wildfire smoke.

The facility infrastructure at the Storm Peak Laboratory serves as a national resource to advance research and research training in high-elevation, atmospheric science. The laboratory also fosters interdisciplinary research collaboration by hosting intensive field campaigns and field training courses, providing long term measurements of meteorology, clouds, aerosols, snow hydrology, and atmospheric gasses. Being part of the NSF/FARE program enhances the ability of the broader scientific community to use SPL instruments and the laboratory as a research site through the NSF/AGS facility request process.

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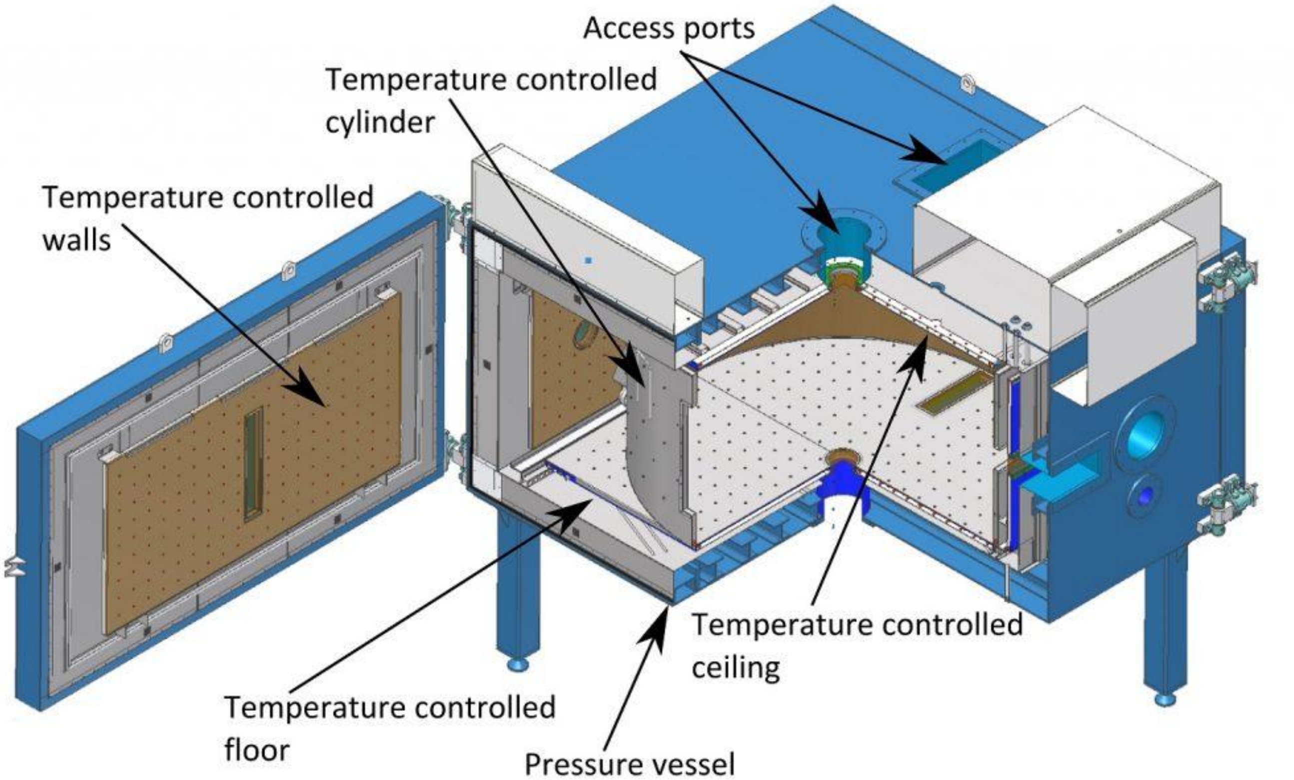
Request Form:
https://www.formpl.us/form/1664196028

Michigan Tech Pi Convection - Cloud Chamber

The **Michigan Technological University Pi Convection-Cloud Chamber** together with an extensive set of supporting instrumentation make a facility that enables measurement of thermodynamics, turbulence, aerosol, and cloud properties for research in the atmospheric sciences. The chamber is designed to simulate cloud conditions within the range of pressures and temperatures that occur in the troposphere. It has been used for research on aerosol-cloud interactions, ice nucleation and mixed-phase cloud properties, cloud optical properties, and moist Rayleigh-Bénard convection. Furthermore, the chamber can generate clouds in a turbulent environment and it can sustain them indefinitely, making long-time observation or averaging possible.

The advantage of this laboratory environment is that clouds don't include the full complexity of the atmosphere but can be reduced to their most elementary features. Clouds can be generated with known boundary conditions and controlled aerosols or pollutants, and can be held in steady-state. This allows researchers to ask specific questions and to study them in a repeatable way. Results can be compared to theoretical and computational models, which can then be extended to the full context of the atmosphere.



The Pi Chamber has a diameter of 2 m and a height of 1 m (volume of 3.14 m^3). A schematic is shown in the figure above. Ports on all sides provide ample access for sampling and optical instruments, and flange covers can be customized according to user needs. The pressure can be controlled to within 1 Pa across the range of tropospheric pressure. The temperatures of the top, bottom, and side walls can be controlled independently, between approximately ±40 °C. Clouds are typically generated by forcing an unstable temperature gradient between the top and bottom plates; they also can be formed by reducing the pressure to create a quasi-adiabatic expansion. In the "mixing mode," the resulting turbulent Rayleigh-Bénard convection flow generates supersaturation through isobaric mixing between the warm, humid bottom boundary and the cold, humid top boundary.

This mixing mode allows for steady-state cloud conditions, which enables long-time sampling and averaging ideal for detailed evaluation and characterization of instruments. The facility is described in more detail by Chang et al. ("A laboratory facility to study gas-aerosol-cloud interactions in a turbulent environment: The Π chamber," *Bulletin of the American Meteorological Society*, **97**, 2343-2358, 2016).

The Pi Chamber facility includes instrumentation for measurement of thermodynamic, turbulence, aerosol, chemical, and cloud properties. It is also possible to bring user instruments to the facility for in-situ or remote measurements, as well as for aerosol and cloud particle sampling. The Pi Chamber team is available to discuss potential experiments and measurements of interest, and to provide guidance on what conditions are achievable.

1885
Michigan Tech

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Request Form:
https://phy.sites.mtu.edu/cloudchamber/nsf-cif/

Fulbright-Kalam Climate Postdoctoral Research scholar Shweta Yadav demonstrating a cold-stage instrument experimental setup

NC State CS

The **North Carolina State Ice Nucleation Cold Stage (NC State CS) Freezing Assay** consists of a machine vision optical system to observe a thermally-controlled surface. The main purpose of the instrument is to observe the freezing nucleation process of supercooled water droplets. The instrument is suitable for studying ambient ice nucleating particle concentrations and laboratory-based process-level studies of the nucleation process.

Problem Description

In the absence of a nucleus, water does not freeze at temperatures below zero Celsius. Substances that cause supercooled water to freeze play a central role in cloud physics. Our group measures the concentration of freezing nuclei in the atmosphere using a cold-stage technique. The experiment is performed by placing droplets on a surface which is observed by a camera. The surface is cooled at a constant rate. Time lapse photography is used to record images of the drops every few seconds. When the droplets freeze, they turn opaque. The change in brightness is detected using an automated image detection code.

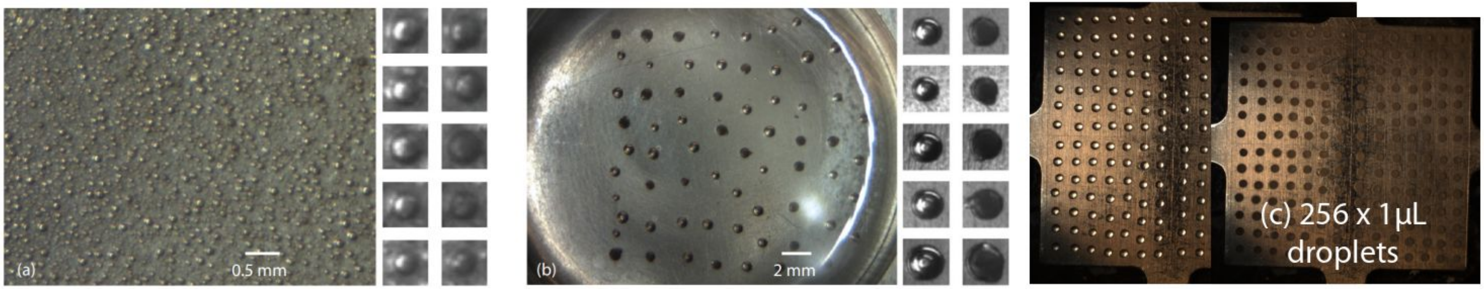

Figure above: Drop volumes used by the NC State CS. (a) A section of the field of view for an experiment using ~0.25 nL immersed in oil. The small images to the right depict enlarged examples of individual drops prior to freezing (left column) and after freezing (right column), (b) same as (a) but for ~150 nL immersed in oil, (c) 1 muL placed on four hydrophobic glass slides. Drops are placed using an electronic pipette. Images in (a) and (b) are obtained using a stereo microscope, the images in (c) with a macro lens.

Software

The code in this repository is used for analysis for 1 ul volume drops shown in the right part of the figure above. Each image is compared to the next colder image with a darkening of the drop indicating a freeze event. Detection occurs in three steps. First, drop locations are identified in the first image in the sequence using a Hough transform for circles. After the location of the drops is identified, each drop location is compared to the same location in the next image by taking a subset of the image including the drop and then performing the following steps: convert the two tiles to grayscale equivalents, subtract the two tiles from each other, convert the grayscale result to a binary image based on a threshold value, and finally perform cleanup.

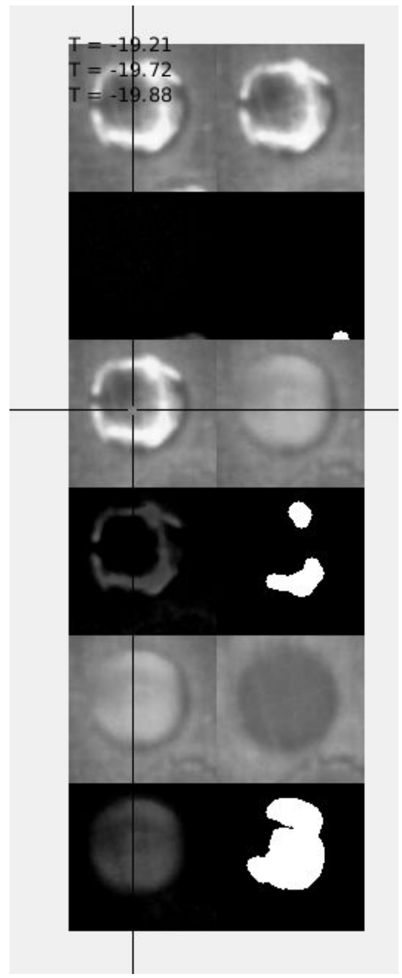

Figure: Drop validation

Impact

CS contributes instrumentation and educational resources to tackle the problem of characterizing the abundance of ice nucleating particles in the atmosphere. As part of CIF, the cold-stage technique will become more widely available to groups that do not specialize in instrument design.

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Request Form:
https://cif-cold-stage.github.io/request/

CLEMSON SP2

The **Clemson University Single Particle Soot Photometer (SP2)** is used to measure the mass of black carbon in individual aerosol particles suspended in air with direct measurement of black carbon mixing state, or the degree to which black carbon is mixed with other, non-incandescing chemical species, on a single-particle level.

The SP2 is kept in user-ready state for laboratory studies, airborne field studies, and ground-based field deployments. The Clemson Air Quality Lab will provide expertise on the instrument operation and data analysis support as needed.

Black carbon or soot is an important aerosol type found in the atmosphere which is generated from nearly every combustion process, including vehicle engines, factories, and forest or agricultural fires. Soot aerosol is highly absorbing of sunlight, which makes it an important component to understanding local heating, micrometeorology, and long-range, long-term climate. Broader access to the SP2 instrument has the potential to advance knowledge in several topics concerning atmospheric aerosol particles.

CLEMSON

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Request Form:
https://cecas.clemson.edu/airqualitylab/sp2/