Millersville University Atmospheric Research and Aerostat Facility (MARAF)

Millersville University has assembled a suite of instruments and associated equipment in support of boundary layer (BL) and atmospheric chemistry (AC) research and research training, and has participated in field research programs in both rural and congested urban areas (e.g. Philadelphia, PA). The MARAF includes:

- **Vaisala DigiCORA® Sounding System MW31 compatible with RS92 radiosondes**
- **Aerostat Sounding System with high wind speed capabilities**
- **ScinTec MFAS Acoustic Sodar with RAE1 RASS extension and enclosures**
- **Sigma Space Micropulse Lidar 4 with co- and cross-polarization backscatter capability**
- **Campbell Scientific 10 meter Surface Flux Tower with:**
  - **CSAT3 3-D Sonic Anemometer**
  - **CS7500 LI-COR Open-Path CO_2/H_2O Analyzer**
  - **Temperature/RH Probe**
  - **Q7.1-L REBS Net Radiometer**
  - **CS 100 SETRA Barometer**
- **Teledyne API criteria gas analyzers and calibration instruments**
  - O_3, SO_2, NO/NO_2/NO_x
- **3-λ TSI Nephelometer**
- **TSI Model 3007 Condensation Particle Counter (surface-based)**
- **Two trailers: 20′ and 16′ with 110/120 V 50 A power supply, and 22,500 W, 65 A generator for remote locations**

System Technical Data:

1. **Vaisala DigiCORA® Sounding System MW31 RS92 radiosonde with GPS capability**

   The DigiCora sounding system will provide upper air profiles of T, RH, p, and wind. Launch frequency will be once every three hours to an altitude of 500 hPa, above which the profile will be terminated (no interest above this level). During morning and evening transition periods the launch frequency will increase to once per hour. The DigiCora will be collocated with the tethered balloon system and the Doppler Lidar.

RS 92 Radiosonde Specifications

Variable	Method	Range	Resolution	Response Time	Repeatability
Temperature	Capacitive wire	-90 to +60 C	0.1 C	< 0.4 s 1000 hPa; < 1 s 100 hPa	0.15 C
Humidity	Thin film capacitor; heated twin sensor	0-100%	1%	< 0.5 s at 1000 hPa, < 20 s at 1000 hPa	2%
Pressure	Silicon sensor	1080 – 3 hPa	0.1 hPa		0.4 hPa
Wind speed	Code-correlating GPS	0 – 60 m/s	0.1 m/s		
Wind direction	Code-correlating GPS	0 – 360 deg	0.1 deg		

2. **Aerostat Sounding System with high wind speed capabilities**

   The tethered balloon sounding system is a versatile multi-balloon platform that can be deployed simultaneously in two modes: 1) to obtained high resolution vertical profiles of state variables

and O_3 concentration to an altitude of 1000 m (with FAA waiver); and 2) to obtain time series at a selected altitude by "parking" the balloon. The balloons have a unique construction that allows deployment in high wind conditions such as LLJs. The tethered system will be deployed near the Doppler Lidar to provide independent confirmation of wind velocity, and to obtain detailed measurements of temperature and humidity profiles for proper insight into LLJ/SBL dynamics. Most importantly, the tethered system will provide an estimate of the depth and strength of the nocturnal inversion as it evolves, which when combined with the Doppler Lidar winds will provide a unique perspective on the NBL. The second balloon can be parked at a layer of interest such as the layer of maximum winds or in the shear zone below the LLJ to obtain 10-second temporal resolution of the advective characteristics of the layer.

Sensor Specification

Variable	Method	Range	Resolution	Response Time	Repeatability
Temperature	Capactive wire	-50 – 60 C	0.1 C	0.2 s	0.15 C
Humidity	Thin film capacitor	0-100%	0.1%	< 0.5 s	2%
Pressure	Silicon sensor	500 – 1080 hPa	0.1 hPa		0.4 hPa
Wind speed	3 cup anemometer	0 – 20 m/s	0.1 m/s		
Wind direction	Digital compass	0 – 360 deg	1 deg		
Ozone	UV Photoabsorption	0-500 ppbv	1 ppbv		

The Tethered Balloon Sounding System can be employed in two modes either separately or simultaneously: 1) as a profiler to delineate the vertical structure of the BL; 2) as a platform for constant altitude integrated samples or time series with fast-response sensors. These balloons have performed to altitudes of 1000 meters, and higher altitudes are possible with FAA approval and under proper safe operating conditions.

Millersville (PI Clark) will be responsible for securing FAA waivers for balloon operations on site. The figure (right) illustrates the deployment of a high wind speed tethered balloon in winter by Millersville students. Balloon size and lift capacity are determined by project objectives. Millersville has three winches that can retrieve balloons up to 300 kg of maximum lift.

3. ScinTec MFAS Acoustic Sodar with RAE1 RASS extension and enclosures

Millersville will provide a ScinTec MFAS acoustic SODAR with RASS extension and enclosures for the continuous profiling of vector wind (wind speed and direction) and virtual temperature. This system must be deployed in a quiet zone free of noise contamination and at a minimum distance of 1 km away from public habitation. The sodar with RASS will provide u_x, u_y, u_z, and T_v profiles from 30 m to 200-500 m AGL depending on attenuation, along with turbulence statistics and C_T (structure function), thereby enabling continuous documentation of the NBL.

- Continuous data from 30-m to 500-m AGL (depending on atmospheric conditions)
- Height resolution 10-m

- Horizontal wind speed accuracy 0.3 m/s
- Horizontal wind speed range 0 to 50 m/s
- Vertical wind speed accuracy 0.03-0.1 m/s
- Vertical wind speed range 0 to 10 m/s
- Wind direction accuracy +/- 3 deg
- Wind averaging time from 10 to 60 minutes (depending on atmospheric conditions time).

Since the sodar evaluates acoustic backscatter signals of small amplitude, it is important to operate the instrument in a quiet environment. In particular, this refers to noise in the range of the frequencies sensed, i.e. the selected operation frequencies. Typical noise sources are: machines and engines (air conditioning), traffic, airplanes, wind at obstacles (whispering trees), birds. Millersville will provide enclosures for the SODAR and RASS (see figure below) to minimize noise, but site selection should take these requirements into consideration.

4. Sigma Space Micropulse Lidar 4 with backscatter capability

The MPL-4 will be located near the surface based aerosol instruments (TSI 3563 and TSI 3007). Even though aerosols are not of direct interest to this project, they can be used as tracers to document advecting structures.

Instrument Description

a) Laser Transmitter: 527 nm, diode-pumped solid state laser, frequency doubled Nd:YLF, 2.5 kHz pulse repetition frequency, >40 μJ/pulse, M2 <1.2, 0.3 mm beam diameter, Windows control software interface. Transmitted beam 6-10 μJ/pulse, expanded to fill telescope aperture.
b) Receiver: Cassegrain design, transmission > 85%, clear aperture 178 mm or larger. Field of view 100 μrad full angle nominal.
c) Lidar Range Resolution: 15, 30, 75 m selectable.
d) Averaging time selection: 1 second to 15 minutes 59 seconds.
e) Detection: Single channel photon counting for MPL Type 4 standard system.
f) Data System and software: Photon counting and analog signal measurement for temperature and laser energy, MPL control and USB interface. Rack mountable chassis. Notebook computer included.
g) Calibrated NIST traceable laser energy monitoring to 7% absolute accuracy over 0-10 μJ.

5. Campbell Scientific 10 meter Surface Flux Tower

The instruments on the 10 meter tower will be used to obtain sensible heat, moisture, momentum, and net radiation fluxes near the surface. This will be one of several flux sites used for documenting bursts of turbulence near the surface, which has been identified as a recurring feature of the NBL when a LLJ is present. It will also provide ground-truth for the balloon-borne profiling instruments and platforms of other investigators. It will be located in a representative area near the profilers.

Sensor	Manufacturer	Model	Parameter	Rate
3-D sonic anemometer	CSI	CSAT3	u,v,w - m/s; T*vs* - deg C	60sps
H2O/CO2 Open-path Gas Analyzer	LI-COR	LI-7500	H2O/CO2 concentration	20sps
Pressure sensor	Vaisala	PTB220B	Pressure - mb	1Hz
Net Radiometer	Micromet Systems	Q*7	Net radiation - W/m2	1Hz

Heat flux plate	Micromet Systems (REBS)	HFT-3	Soil heat flux - W/m2	1Hz

6. Surface-Based Instruments and Sensors

The following instrumentation is intended for surfaced-based meteorology and chemistry. In addition to providing a continuous record of criteria gas concentrations at the surface, which is essential to evaluating the correlation between the downward mixing of pollutants and the surface signature, it will provide a measurement comparison with the DOAS instrument.

Variable or Instrument	**Method**	**Range**	**Resolution**	**Response Time**	**Repeatability**
Temperature	Capactive wire	-50 … + 60 C	0.1 C	0.2 s	0.10 C
Humidity	Thin film capacitor	0 …100%	0.1%	< 0.5 s @ 20 C	2%
Pressure	Silicon sensor	500 … 1080 hPa	0.1 hPa	N/A	0.4 hPa
Wind speed	3-cup anemometer	0 … 20 m/s	0.1 m/s	N/A	N/A
Wind direction	Digital compass	0 … 360 deg	1 deg	N/A	N/A
PM2.5 Conc (DustTrak Model 8520) Temp range 0 – 50 C	90 deg Laser-diode photometry Flow Rate 1.7 L/min	0.001 … 100 mg/m^3	± .1% of reading or 0.001 mg/m^3	N/A	N/A
Condensation Particle Counter (TSI Model 3007) Temp range 0 – 50 C	Cloud chamber w/ optical scatterometer Flow Rate 700 cc/min	0.01 … 1.0 µm; 0 …100,000 cm^{-3}	1 particle cm^{-3}	N/A	N/A
TSI 3-λ Nephelometer Model 3563 Scatter-coef of airborne particles	Optical integrating nephelometry;450 nm (blue), 550 nm (green), 700 nm (red). Flow Rate 20-200 L/min	Sensitivity Blue/green 1.0 x 10^{-7} m^{-1} Red/IR 3.0 x 10^{-7} m^{-1}	Drift Less than 2.0x10^{-7} m^{-1} at 30-sec ave time	< 10 sec	
O_3 API model 400A	UV absorption EQOA-0992-087	0-100 ppb / 0-10 ppm user selectable	< 0.6 ppb per EPA definition	< 10 sec per EPA definition	N/A
SO_2 API model 100A	Fluorescence EQSA-0990-077	0-50 ppb / 0-20 ppm auto ranging	0.4 ppb RMS	< 20 sec per EPA definition	N/A
NO/NO_2/NO_x API model	Chemiluminescence RFNA-1194-099	0-5 ppb / 0-2000 ppb	0.4 ppb RMS	< 20 sec per EPA	N/A

200A		user selectable		definition	
CO API model 300A	Gas Filter Correlation	0-1 ppm / 0-1,000 ppm			

7. Millersville 20′ and 16′ trailer and Operations Center

Millersville University can provide trailers to serve as on-site operations center for projects. The trailers are equipped with computers, calibration equipment, and the data acquisition systems for the DigiCora rawinsonde and the tethersonde system. An Internet feed and 50 amps current are needed on-site for full operations in the field, or for non-AQ studies, a generator is used to power the trailers.