1. How to carry MiniWRAS and two sets of PocketLab/smartphones

The MiniWRAS is required to point towards where we walk according to Durag. So this requires mounting a 19 pound device on the chest of the user. It has a handle but this requires carrying a heavy device one on side, which gets tiring quickly.

We use a Dana Designs “Overkill” Alpine mountaineering backpack designed to carry heavy loads. We use two loops made of tubular webbing tied with a water knot. These are anchored to the backpack shoulder strap loops above the chest strap. We use locking carabiners on the end of each webbing loop, pass it through the handle of the MiniWRAS, and clip it to the backpack shoulder strap.

The phones and PocketLabs each have a quad lock adaptor attached with 3M adhesive and locked to a plastic pipe with four quadlock bicycle mounts. Tubular webbing passes through the pipe and there is a water knot loop at each end with a locking carabiner.

We found Bluetooth was less reliable when the smartphone was in a jacket pocket near the device. A see through mesh pocket worked. The procedure above has no physical interference between the PocketLab and the smartphone, and the phone is positioned as close as possible.

2. Collect humidity data, and PocketLab PM2.5 comparison data

We carry two PocketLabs connected to two Iphone 7 or above. This allows us to compare PM2.5 data from two PocketLabs and a MiniWRAS on a graph automatically generated by the auto-grapher software we wrote.

How to connect to with the iOS App:

1. Open the Apple App store.
2. Search PocketLab. Download the PocketLab App.
3. Make sure Bluetooth is turned on in your settings.
4. Open the PocketLab App.
5. Turn the PocketLab Air on. It should then automatically connect.
6. You'll default to a view of all of the sensor graphs. You can switch to view graphs on their own using the switch graph icon in the upper left corner of the screen.

How to export your data:

1. After recording a data trial, click the "Export Data" button in the lower right corner. 2. You will then be given the option to save locally (directly download the .csv file to their computer/phone) or save to Google Drive. I would probably recommend saving to Google Drive as it will then be easier to share. 3. Next, have them either email their .csv file or share it directly with you via Google Drive.

Preferred export method:

Save data to Pocketlab cloud software, "CloudLab". by clicking "Upload to CloudLab" after a data recording. Then you are asked to either login or create an account. It requires an internet connection to save the data to CloudLab, so keep that in mind. Then save their data to a "Timeline" in CloudLab. After saving to CloudLab, you can then go back and view the graphs at anytime from other computers/devices. The graphs will look as they do in the web app. From CloudLab, we can still download the data as .csv files. Always download a .csv file of the recorded data. "CloudLab" is beta software right now and Pocketlab is doing a major overhaul of it this summer

These are attached to the backpack shoulder strap facing forward, in front of the person as you walk.

3. MiniWRAS & Pocket Lab Procedures
For mobile mapping / graphing of diesel particulate

Pre- Deployment:

- Charge all devices: MiniWRAS, two phones, and two pocket labs.
- Insert USB device (flash drive with Grimm formatting/calibration folder) into the MiniWRAS BEFORE START.
- Disable auto-lock for GPS collection on the collection phones. (under “display and brightness” for iPhone). Having another navigation app giving directions will have the same effect.
- For evening collection have a flashlight / headlamp ready.

Start Deployment:

- Launch Strava on phone and press START.
- Start Pocket Lab by pressing button (light quickly flashes red and green). Launch Pocket Lab application, pair device (Light slowly blinks magenta), PRESS RECORD. Repeat for each redundant device.
- Press ON switch on MiniWRAS, wait 3 mins or until the battery indicator lights up and beeps. Remove aircover, then press START (Start light should turn solid and fans will begin to run).

- Rig the MiniWRAS to a backpack or carrying apparatus along with the pocket lab / phone array.

During Sampling:

- Face collection ports straight ahead and begin walking. Do not to press any buttons.

End Deployment:

- Press STOP on pocket lab app, export file.
- Stop MiniWRAS, wait 3 mins or until light stops flashing, power down by pressing the off switch, take out the USB device with the collected data on it.
- Stop GPS recording in browser & export to your phone.

Data Processing:

- Use Auto-Mapper/Grapher:
    - For maps upload the .cvs file to google drive, open as a google sheet, set the sheet to public, and copy the sheet's link.
    - Paste this link into the airmap found here https://cdaringe.github.io/airmap/
- Use MiniWRAS Autographing software. https://observablehq.com/d/8ec91cda01c26e0c
- Grimm software graphs target and non-target particles.
- Collect HRRR Sounding from NOAA https://www.ready.noaa.gov/READYamet.php & generate pasquil index using excel file.
- Compile all files into google drive for easy access.

4. Converting from particle count to mass:

We wrote software that converts particle counts to mass expressed as micrograms per cubic meter (µg/m3) and plots the sum of the mass of 13 MiniWRAS channels less than .5 microns. The software plots colored dots on an online MapBox map showing the concentration of airborne particles .01 to .449 microns.

"The accumulation mode of diesel engine particulates is made of sub-micron particles of diameters typically ranging from 30 to 500 nm (0.03-0.5 nm)"

https://dieselnet.com/tech/dpm_size.php

The nucleation mode of diesel is as small as 10 nm.
This converts to .01 to .5 microns.

California risk assessments, and DEQ particle monitors use mass expressed as µg/m3 for diesel particulate. The MiniWRASA and the Grimm software provide µg/m3 only for PM2.5; diesel particulate (.5 microns and smaller) is reported as particle counts.

The conversion equation from particle count to particle mass provided by Durag by request is shown below:

$$m_i = \frac{1}{6}\pi D_i^3 \rho$$

The mass of an individual particle can be calculated given its diameter (**D_i**) and density (**ρ**); multiply this by the number of particles to calculate the total mass of particles of a specific diameter or in a specific size bin. To convert this total mass of particles to a particle density (µg/m^3), you then need to divide by the total volume sampled (ρ = mass/volume).

This total volume can be calculated from the duration of the sample (one minute, etc.) and the sample flowrate of the instrument (1.2 lpm), i.e., in one minute the device samples a total volume of 1.2 liters (1.2 liters = 0.0012 m^3). Particle density in units of µg/m^3 would then be equal to the total mass of particles sampled in one minute divided by the total volume sampled in one minute, 0.0012 cubic meters.

We received a sample MiniWRAS spreadsheet from Durag and calculated total diesel particulate mass in the following spreadsheet: "1371_aaar_tuesday.dat.xls"

The conversion requires a value for the density of soot, which we used 1800kg per cubic meter.
"Usually, the true density of freshly emitted soot particles is assumed to be close to 1800-1900 kg/m3 (Bond et al., 2013; Dobbins, Mulholland, & Bryner, 1994"

https://www.sciencedirect.com/science/article/am/pii/S0021850219300114

This is the Excel conversion equation we wrote from the information above:

= PI() / 6 * POWER(nm / 1000000000,3) * rho_true * D2 / v_air / 1000000000

Here are the values used in the equation:

Value	Name	Unit	Description
1800	rho_true	kg / m^3	diesel particulate density
3.141592654	pi	1	spherical particle volume
0.0012	v_air	m^3	MiniWRAS volume air/min.

Here are the variables used in the equation:

nm = (column header + next column header)/2
rho_true = 1800 (kg / m / m / m)
pi = 3.14159265359 (unitless)
D_i = particle_bucket_nm / 1000000000 (meters)
v_air = 0.0012 (m * m * m)
m_i = pi / 6 * D_i * D_i * D_i * rho_true (kg)
rho_total = m_i / v_air (kg / m / m / m)
rho_microg = rho_total / 1000000000 (micrograms per cubic meter)

Upon review by Durag, we were told our conversion was correct. MiniWRAS data contains 41 evenly spaced channels from .01 to 35 microns. Row headers in MiniWRAS data are the bin low boundary size. That column reports all the particles from the low boundary size up to the size of the next channel's low boundary. We use the calculated midpoint of each channel.

5. Determine the percentage of diesel particulate for samples .5 microns and smaller:

All particles .5 microns and smaller are diesel particulate minus the percentages of woodsmoke and brake dust:

TBD% woodsmoke - during similar inversions, we will sample highway exposed areas to areas not highway exposed to determine the expected percentage of woodsmoke near highways. EPA NATA also reports modeled annual averages of woodsmoke and diesel particulate for Portland.

Ultrafine particles near highways are less than 12.5% brake dust - based on citations below, all roadside particulate is 58.5% of is ultrafine diesel particulate and 8.4% brake dust. 8.4 / (58.5 + 8.4) = 12.5%. This includes ultrafine brake dust particles larger than our cutoff of .5 microns, which is why I include "less than" - it looks like brake dust is 10% or less of particles .5 microns or less.

Works cited:

Diesel powered vehicles are only 6% of Oregon vehicles on the road, they emit 60 - 70% of all particulate emissions from all on-road vehicles combined.

Oregon DEQ
www.oregon.gov/deq/FilterDocs/DieselEffectsReport.pdf

More than 90% of DPM is less than 1 µm in diameter

CARB
https://ww2.arb.ca.gov/resources/overview-diesel-exhaust-and-health

Brake dust is up to 20% of traffic-related particles.

Liza Selley, a postdoctoral research fellow at the University of Cambridge
https://airqualitynews.com/2020/04/16/air-pollution-from-brake-dust-may-be-as-harmful-as-diesel-exhaust-on-immune-cells/

citing Air Quality Expert Group to the Department for Environment, Food and Rural Affairs; Scottish Government
https://uk-air.defra.gov.uk/assets/documents/reports/cat09/1907101151_20190709_Non_Exhaust_Emissions_typeset_Final.pdf

ultrafine dust particles of less than 2.5 µm account for about 42% of brake dust

Zhang et al. Enclosure Design for Brake Wear Particle Measurement Using Computational Fluid Dynamics

https://www.mdpi.com/1996-1073/14/9/2356

6. **Grimm MiniWRAS & Pocket Lab deployment procedure for mobile mapping / graphing of diesel particulate.**

Pre- Deployment:

- Charge all devices: MiniWRAS, two phones, and two pocket labs.
- Insert USB device (flash drive with Grimm formatting/calibration folder) into the MiniWRAS BEFORE START.
- Disable auto-lock for GPS collection on the collection phones. (under "display and brightness" for iPhone). Having another navigation app giving directions will have the same effect.
- For evening collection have a flashlight / headlamp ready.

Start Deployment:

- Launch Strava GPS application and press START.
- Start Pocket Lab by pressing button (light quickly flashes red and green). Launch Pocket Lab application, pair device (Light slowly blinks magenta), PRESS RECORD. Repeat for each redundant device.
- Press ON switch on MiniWRAS, wait 3 mins or until the battery indicator lights up and beeps. Remove aircover, then press START (Start light should turn solid and fans will begin to run).
- Rig the miniWRAS to a backpack or carrying apparatus along with the pocket lab / phone array.

During Sampling:

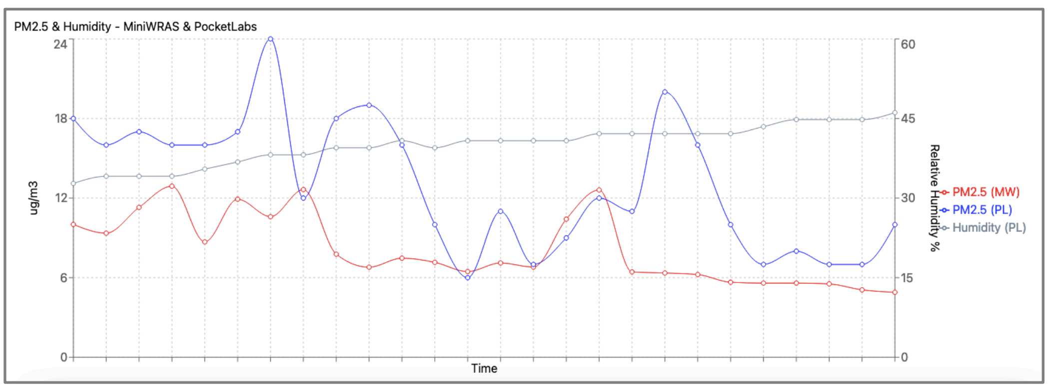
- Face collection ports straight ahead and begin walking. Careful not to press any buttons.

End Deployment:

- Press STOP on pocket lab app, export file.
- Stop MiniWRAS, wait 3 mins or until light stops flashing, power down by pressing the off switch, take out the USB device with the collected data on it.
- Stop GPS recording and export the .gpx file.

Sample Data Processing:

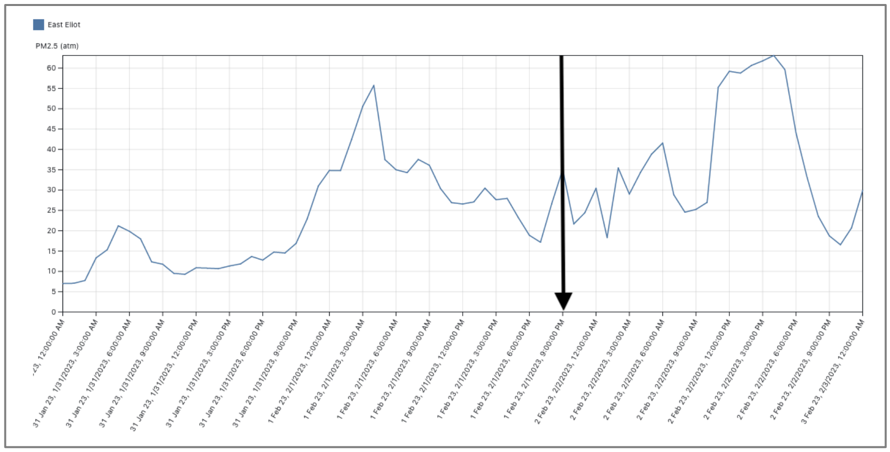
- After each sample there should be three files. A .dat file from the MiniWRAS, a .csv file from one of the Pocket Labs, and a .gpx file from the Strava app.
    - Paste only these three files into the Airmap here: https://cdaringe.github.io/airmap/
    - Then click "Submit". One the next page DO NOT CHANGE the reference numbers at the top. Click "Continue".
    - The color-coded map shows the MiniWRAS sample. Select the particle size you wish to graph. For our latest report we used option 1: PM 0.5 ug/m3 (derived) and option 3: PM 2.5 ug/m3.
    - Adjust the map zoom as needed and screenshot the map. For PC use WINDOWS+SHIFT+S and crop out the browser window to get a clean map image. On mac this is done with SHIFT+COMMAND+5 which opens the screen capture window. Find the file where the image is sent and name it to keep track.
    - Clicking "Show Charts" opens the MiniWRAS PM 2.5 / PocketLab PM 2.5 / PocketLab Humidity Graph. This chart let you compare the PM 2.5 readings from the MiniWRAS and the PocketLab as well as humidity data which affects particle size. Screenshot this graph using the same method listed above.



Purple Air Data Processing:

- The graph above shows how we compare mobile sample readings to stationary Purple Air readings from nearby.
    - Compare the MiniWRAS sample route to the purple air map here: https://map.purpleair.com/1/mAQI/a10/p604800/cC0#11/45.4972/-122.6937 and select a sensor near the center of the sample area or along the route.
    - Open the PCA Purple Air Auto-Grapher here: https://observablehq.com/d/da04a12af18af536 and look for the sensor you wish to graph. If it is not there then it may be a new sensor or one that is not added to the Auto-Grapher yet. Find the closest graphable outdoor sensor.

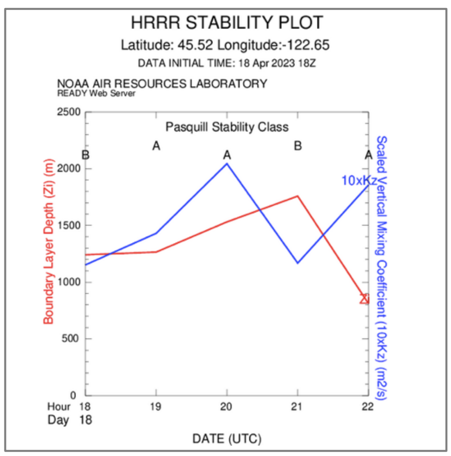
- The date and time of the sample should be in your local timezone, as is the purple air data. Your sample timestamps can be found in the Pocketlab .csv file. For the purple air graph, select a date range that centers the sample time. We chose a 3 day range with the day of the sample in the middle of the graph. You may wish to "zoom in" and select a shorter date range.
- Group by "Hourly" and adjust the "Tick multiplier" to show enough time stamps to make your graph easy to read, then screenshot here or select the three dots on the top left corner, "download svg" and open the file in a new tab. Then use CTRL++ to zoom in and then screenshot for a big HD graph. Repeat for multiple sensors. In the example below, we edited the image to include a black arrow at the time of sampling.



Calculate Inversion using NOAA Archive

- NOAA has publicly available archives of atmospheric inversion data.
  - Access the archive here:

    https://www.ready.noaa.gov/READYamet.php and add the latitude and longitude coordinates to the nearest hundredths place for example 45.56 -122.67 this is sufficient precision for inversion data. Click "Continue"
  - Previously we have used "sounding" data to calculate the Pasquil Stability from the temperature readings at various altitudes. This does not give information on the inversion ceiling. For best results use the "stability time series" and select HRRR (3km, 1hourly, US) and click "Go"
  - NOAA archives their data using Universal Time Coordinated UTC, and 24 military time. Be sure to convert your sample time to UTC. The clock app on most smartphones has a world clock, there is also a chart on the previous NOAA page labeled "what is UTC, GMT, Z time?", or a helpful website here: https://www.worldtimebuddy.com/. Be sure to account for daylight savings time changes.
  - The archive lists dates as follows YYYYMMDD_Hour_Hour_Hrrr. Select the time frame you wish to graph and click "Next".
  - Please note we have experience occasionally the last hour of a graph period is cutoff and not included in the final graph. In addition, selecting a later hour under "Starting date/time" has yielded an error message. If the sample time is cut off, use readings from either side of the sample. For example, 9pm is not listed, note the inversion data at 8pm and then go back a page and select the next time frame YYYYMMMDDD_Hour_Hour that will give you 10pm.
  - Enter the access code at the bottom of the page and click "Get stability" A graph is generated

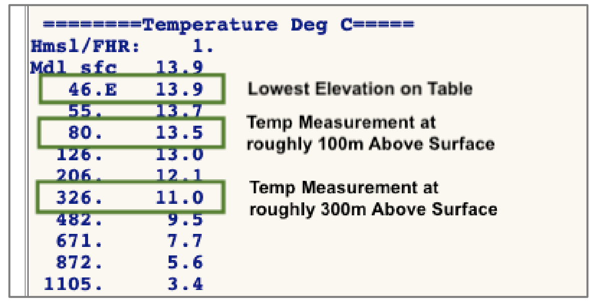


with two lines and letters at the top. For the hour you need, note the letter A-G on top. This is the pasquil stability index. The red line displays the inversion ceiling, note its altitude in meters. You may also wish to screenshot the graph for later reference.

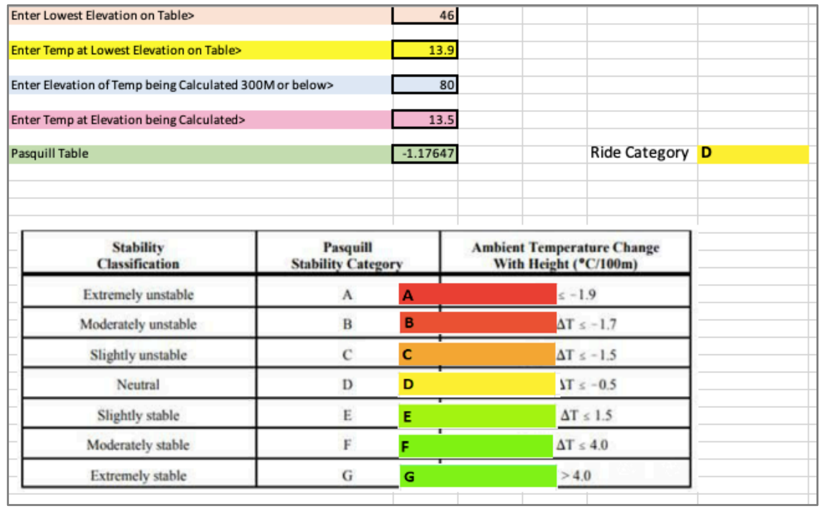
Alternate Inversion data using NOAA HRRR Soundings, and the Pasquill Inversion Tool

- This is another way to calculate the inversion class A-G using NOAA archives.
  - Access the NOAA archives here https://www.ready.noaa.gov/READYamet.php and enter the latitude and longitude of the sample. Click "Continue"
  - Under "Sounding" select "HRRR (3km, 1 hourly, U.S)." and click "Go".
  - Select the time frame you wish to view and click "Next". Remember to convert your local sample time to UTC.
  - For "Time to plot" select the hour for your sample in UTC.

- For “Output options” select “Text only” and for “Graphics” select “Text listing”. Enter the Captcha and click “Get Sounding”.
- A long string of text will appear, for the next steps we only need the text box labeled “===Temperature Deg C===”. This info is also in the larger box above it which you may wish to screenshot for records. Below the image shows exactly which measurements you need.



- Using the Pasquill Calculation Tool in Excel enter the surface elevation and temperatures, then the elevation closest to 100m and its temperature. This will give an inversion class A-G shown in the second image. Repeat the step for the elevation at 300m for a comparison.
- This method while useful does not clearly indicate the inversion ceiling like the first method.



8. Computer Programming for automatic MiniWRAS data mapping.

Cascadia Action has documented the entire process of computer programming the procedures explained above. However we have not been able to include this writing in time for the release of this report. That will be added soon.