Update: Dust Detection and Alert System
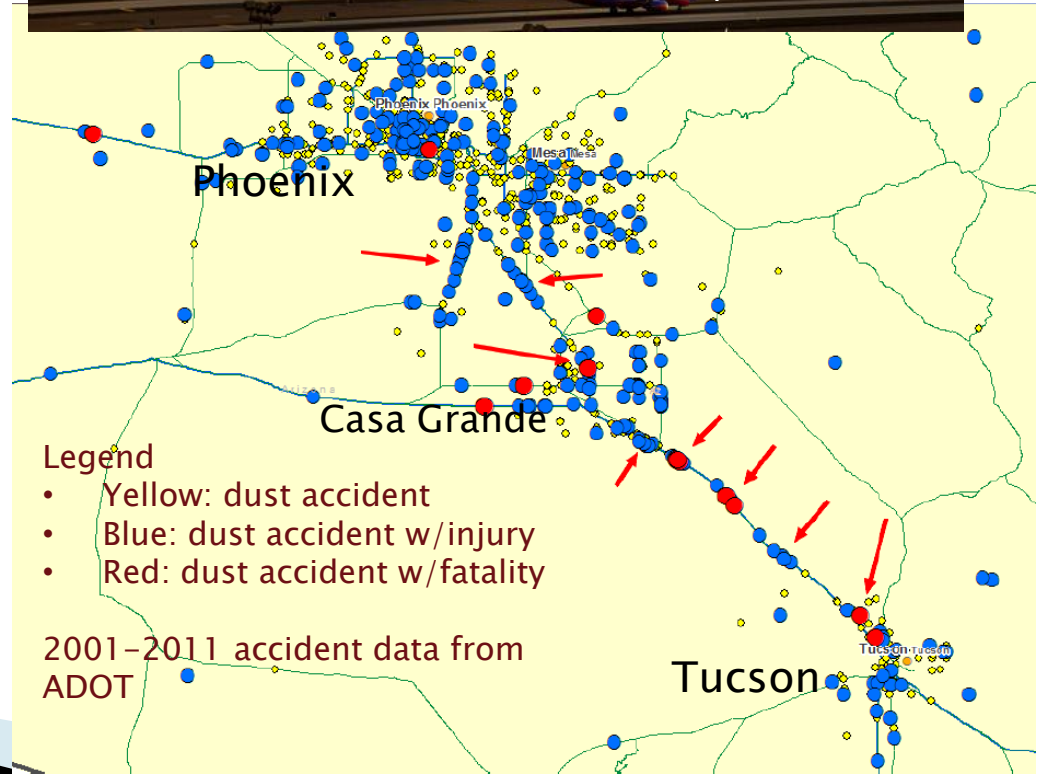
Ken Waters, NOAA/NWS Phoenix

Casa Grande, March 19, 2015

Background

- Every year Arizona experiences blinding dust storms that lead to accidents and fatalities along high-speed highways

- Certain areas are known to be particularly prone to these events

(Photo: Rob Schumacher, The Arizona Republic)

Phoenix

Casa Grande

Legend
- Yellow: dust accident
- Blue: dust accident w/injury
- Red: dust accident w/fatality

2001-2011 accident data from ADOT

Tucson

Dust Storm Background

- Common in Arizona and the desert southwest

- Can be classified by three different causes:

  - Monsoonal severe thunderstorms (June-Sept)
    - Very strong outflow boundaries pushing away from microburst; can reach well above the surface (~ 8-10k feet); can travel for 100-200 miles
    - Somewhat difficult to predict until outflow boundary has formed
    - Typically easy to see due to immense scale; biggest impact may be health-related through transmission of Valley Fever contagions

  - Winter large-scale gradient wind events
    - Synoptic scale, fairly easy to predict

  - Micro-scale "dust channel" events
    - Very difficult to predict and detect
    - Often leads to surprise zero visibility conditions on high-speed highways and resulting mass collisions with injuries and fatalities
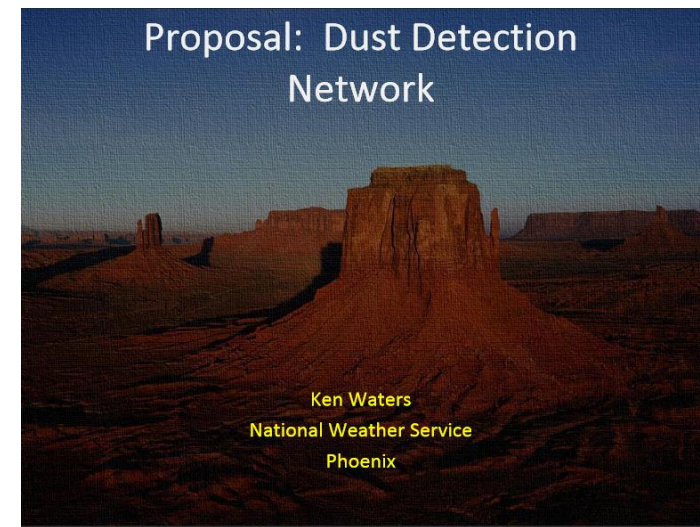
PROBLEM: Detection of Dust Storms

▸ Poor observational data sources

  ◦ RADAR: Most common area between Phoenix and Tucson lies far away from Doppler weather radar
    · Radar beam rises away from the antenna and so misses early detection of dust storm conditions which are surface-based

  ◦ SURFACE OBS: Sparse surface observational network including only one weather reporting site (KCGZ) with visibility values for a 90 mile stretch of Interstate 10

  ◦ SATELLITE: Visible satellite often not useful due to either (a) overriding cirrus clouds and/or (b) nighttime

▸ Illustrates need for a method to get real-time ground reports

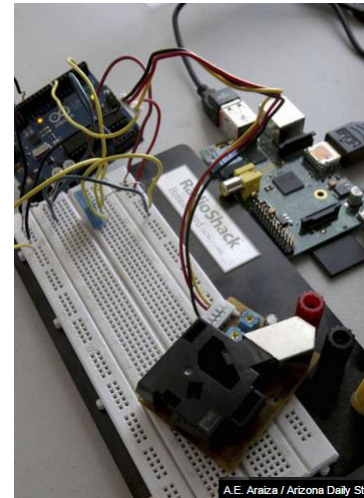# New Idea: Utilize low-cost New Technologies to Detect Dust Storms

- Instead of expensive (~> $30k each) visibility sensors, why not measure air quality using newly available low-cost sensors?

- Idea first introduced at the 2013 Dust Storm Workshop in Casa Grande)

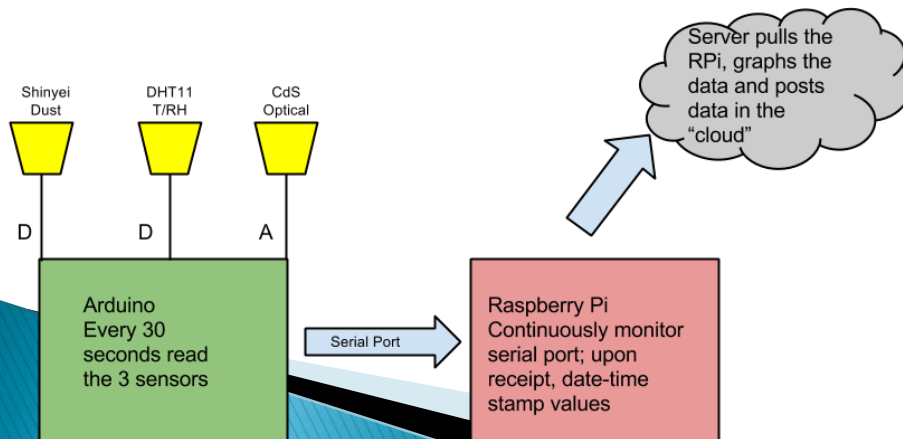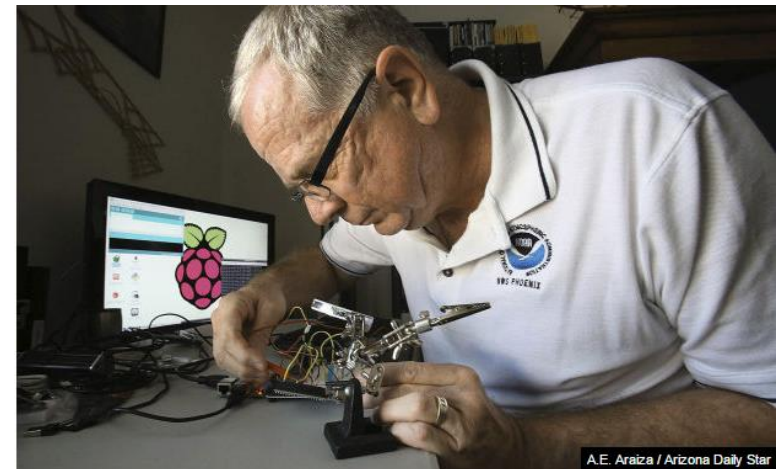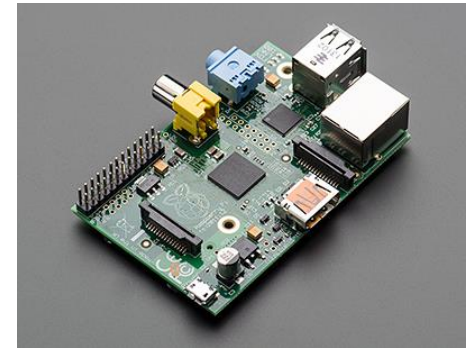- An example of the Internet of Things as highlighted during the conference opening

Proposal: Dust Detection Network

Ken Waters
National Weather Service
Phoenix

http://www.wrh.noaa.gov/psr/dust/2013/presentations/Waters_DDN.pdf

System Design

- Takes advantage of low-cost, readily available parts

- Cost: $100-120

- Use available power and bandwidth

- Free Open Source Software in Linux: Python, Perl, GNUPlot

Arduino

Raspberry Pi

A.E. Araiza / Arizona Daily Star

Server pulls the RPi, graphs the data and posts data in the "cloud"

Shinyei Dust   DHT11 T/RH   CdS Optical

D   D   A

Arduino Every 30 seconds read the 3 sensors

Serial Port

Raspberry Pi Continuously monitor serial port; upon receipt, date-time stamp values
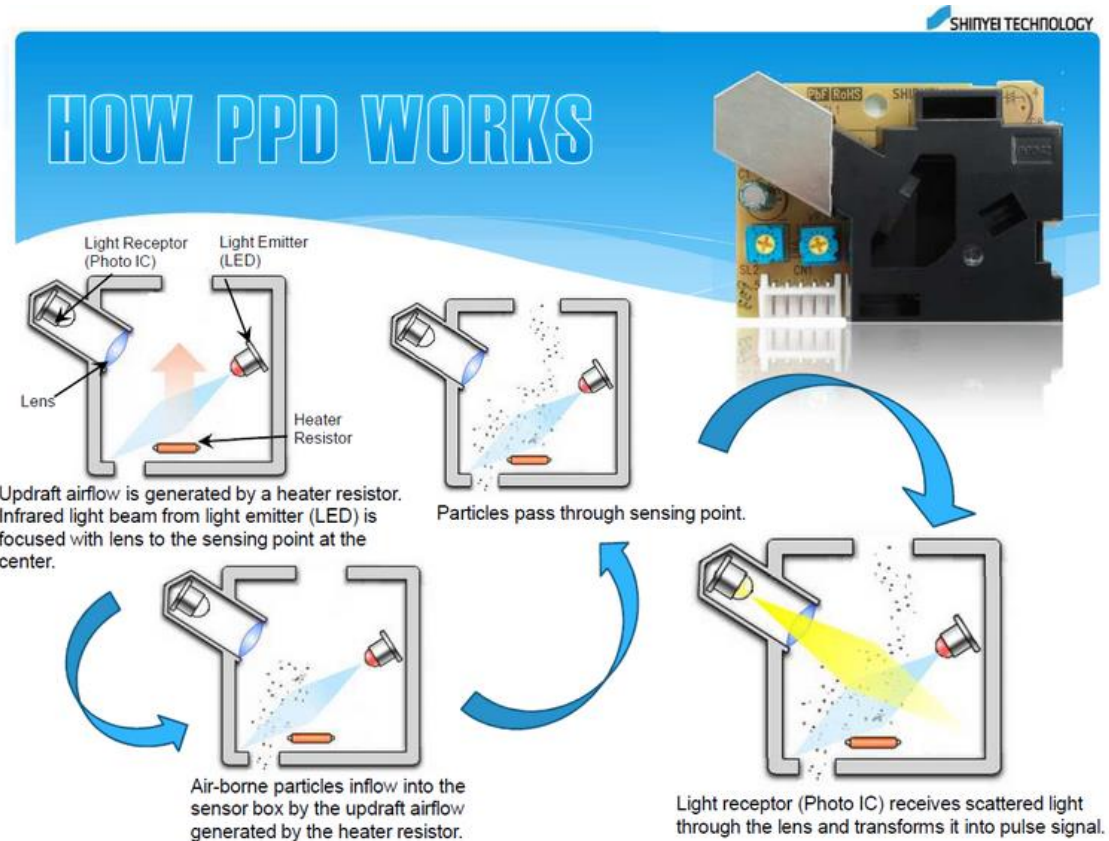
A.E. Araiza / Arizona Daily Star

Sensor

▸ Shinyei PPD
  ◦ Uses optical sensor to detect particulate density
  ◦ Has ability to report both PM10 and PM2.5 values

SHINYEI TECHNOLOGY

HOW PPD WORKS

Light Receptor (Photo IC)
Light Emitter (LED)
Lens
Heater Resistor

Updraft airflow is generated by a heater resistor. Infrared light beam from light emitter (LED) is focused with lens to the sensing point at the center.

Particles pass through sensing point.

Air-borne particles inflow into the sensor box by the updraft airflow generated by the heater resistor.

Light receptor (Photo IC) receives scattered light through the lens and transforms it into pulse signal.

seeed WIKI

Page   FAQ

Grove - Dust Sensor

Dust Measurement

- The PPD24N has capability to report both PM2.5 and PM10 values

- Units measured in my experiments were PM10 (< 10 micron diameter) particles per 0.01 cubic feet

- Another comparable sensor is Sharp GP2Y10

Source: http://en.wikipedia.org/wiki/Particulates#mediaviewer/File: Airborne-particulate-size-chart.jpg

Process

- Air Quality sensor takes observation every 30 seconds, passes to Arduino and then Raspberry Pi which sends observation into the "cloud"

- New web site set up for posting results:

    http://monsoonsafety.org

- If possible alert conditions are detected the Raspberry Pi sends an alert e-mail to NWS, ADOT, responders

- GOAL: have enough low-cost sensors reporting in real-time to create a dense network, viewable in near-real-time on the Internet.

Siting

▶ Most desirable:

◦ Locate near known existing sources of dust (especially fallow/disturbed land)

◦ Locate close to typical high monsoon thunderstorm activity

◦ Access to power
  - Alternative: solar power

◦ Access to Internet
  - Alternative: ham radio Automatic Packet Reporting System (APRS)

Collaborative Data

▸ Also collected for this experiment:

- One-minute webcam images
  - Useful for visual confirmation

- Automated Weather Station data (Davis Instruments Vantage Pro 2)
  - Often captures a dramatic simultaneous drop in T and increase in Td as outflow boundary passes
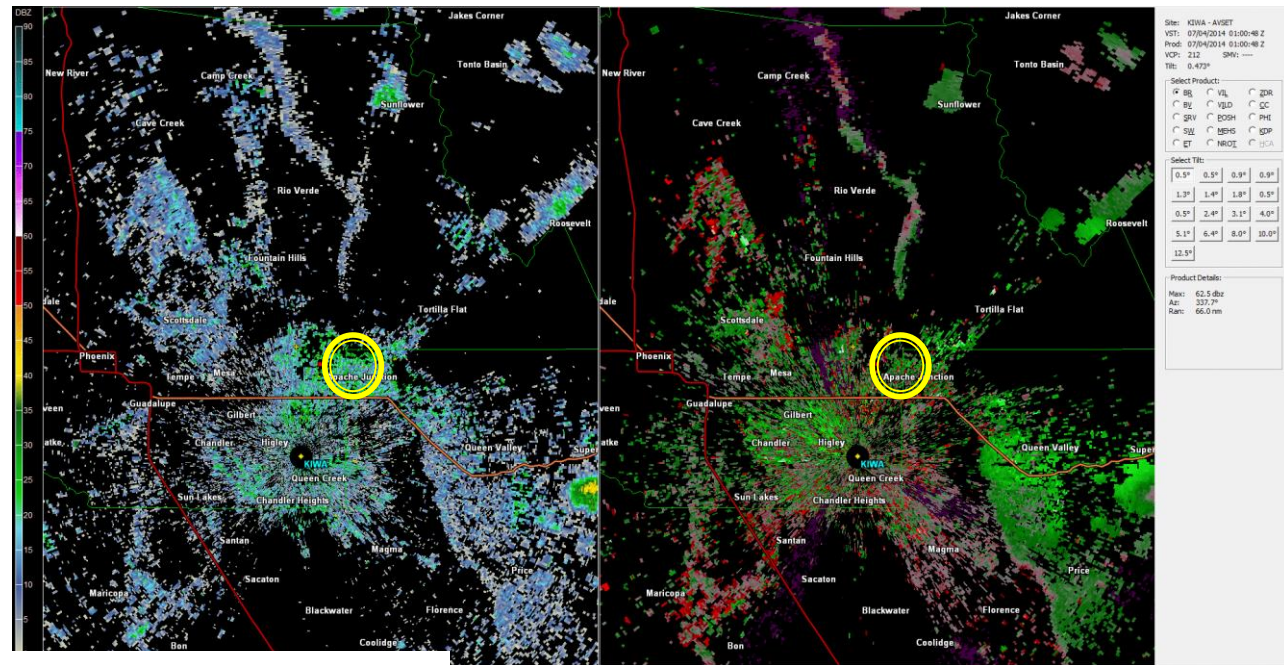
RESULTS

▸ Since March 2014 one site was installed (east Mesa) and collected data through October 2014.
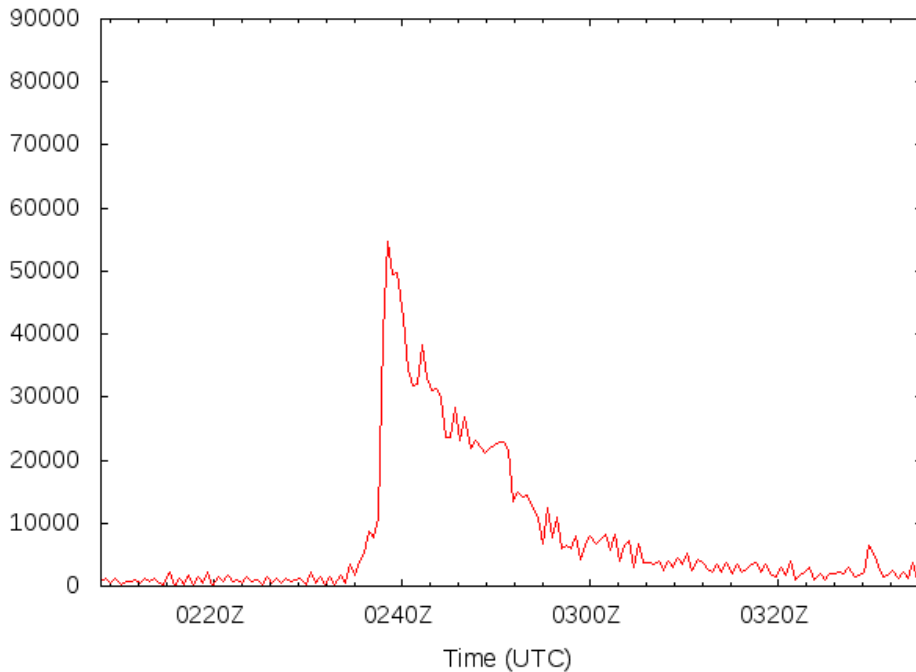
▸ Four logged events:

Date	Dust Storm Warning Issued?	Dust Sensor Detected	Webcam
July 3rd	YES: 7:02 pm	Yes	Vis ~ 1/8 mi
July 8th	YES: 9:26 pm	Yes, initial peak then downburst overhead	Vis estimated ½ mile then downburst
July 15th	NO	Yes, low peak	Vis no lower than 3 miles
Sept 4th	YES (Pinal Co): 7:03 pm	Yes	Vis estimated 1 mile

July 3rd

Classic monsoon severe microburst outflow signature

3 July 2014 East Mesa Dust Sensor

E-Mail List for Updates on Dust Storm Detection System

- This is a different list from the Dust Storm Workshop List (invites)

- To be added to either list contact Ken (ken.waters@noaa.gov)

January Update --- Dust Detection System   Inbox   x

Ken Waters - National Weather Service <ken.waters@noaa.gov>   11:33 AM (20 hours ago)
to bcc: _NWS

Hi and Happy New Year to all of you!

This is the first of what will be a (hopefully) regular monthly update on the progress of our proposed Dust Detection Network system.

First of all, thanks for your interest in the system. I received a surprisingly large number of requests to be added to this mailing list and so we are pleased to see the level of interest.

I have a number of updates to pass along to you today:

[1] Upcoming annual Dust Workshop

Our 4th annual Dust Storm Workshop is scheduled to be held again this March. You should be receiving an official invite within the next few days. It will be in the same location. We anticipate a full house again and may have to cut off registration for that reason so we advise you to be sure to reserve a spot if you plan on attending. Please look for the forthcoming e-mail.

[2] Presentation to the American Meteorological Society conference Jan. 6th

I made a presentation on our dust detection network at this conference last week. It seemed to be met with a lot of interest. The presentation can be viewed as follows:

Abstract: https://ams.confex.com/ams/95Annual/webprogram/Paper269966.html
PDF version without loops: http://monsoonsafety.org/dust/AMS2015.pdf [10 MB]
Full version with loops: http://www.wrh.noaa.gov/psr/dust/AMS2015.pptx [62 MB]
AMS Walkthrough with audio from the conference: will be available in early February; use abstract link above to access

[3] Network Status

At this time we have two live sensors installed and running. One is the East Mesa station which ran for much of 2014. The other is currently indoors [for testing purposes] at the NWS office in Tempe (co-located with the Salt River Project). We are hopeful to have one or possibly two sensors deployed this week or next and are working with a few people to make the arrangements.

[4] First Looks: Website

We are in the very early stages of setting up the website to collect the sensor observations. Here is a link to our map interface showing the two live stations right now: http://monsoonsafety.org/dust/dustMap.php. As you can tell it uses the Google Maps interface for the map. Individual station data can be queried by clicking on the station. Again, this is a very first mockup and so we can't guarantee it will be working smoothly but it's a start. If you have any suggestions or comments feel free to send them to me and/or daniel.leins@noaa.gov.

[5] Sensor Enclosure

I first must confess I have very limited building mechanical skills but I did manage to put the entire package snugly inside of an inexpensive plastic enclosure (thanks Ikea!) and cut out holes for the power AC connector as well as an opening for the dust sensor to collect environmental data. This is just a first step but at least it will hopefully be more weather-ready. A couple of the earlier packages got compromised by monsoonal heavy rains. We are certainly learning on this front and will continue to experiment with improvements in enclosures. A couple of the items we are carefully evaluating include ensuring a sufficient opening for the sensor, potential heat effects on the circuit boards inside the package, possible heat mitigation steps we could take on the enclosure, concerns about the cracking of the polypropylene plastic from the extreme AZ heat, and protection of the package from rainfall.

That's all for now. Please let me know if you want to add someone else to this mailing list and also if you have any questions or comments on any of these items.
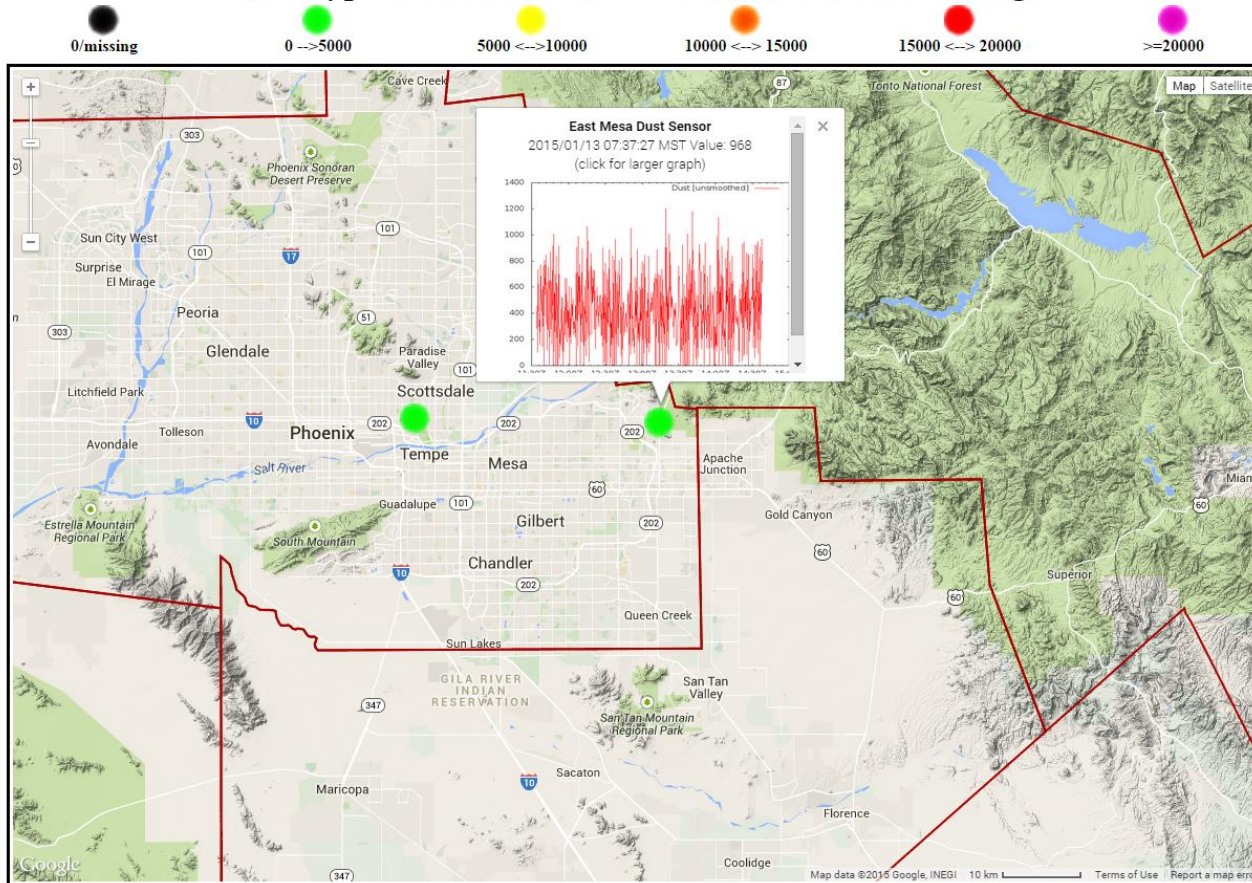
Regards,

Ken

New Website --- monsoonsafety.org/dust

Prototype Real-Time Dust Detection Network Web Page

Recent Enhancements

▸ Set up the Raspberry Pi's to produce their own dust sensor graphics

▸ Set up the Raspberry Pi's to automatically transfer both data values and graphics to centralized web site

▸ Added function to monitor temperature of Raspberry Pi (for diagnostic/maintenance purposes)
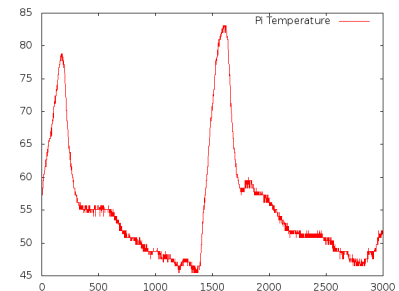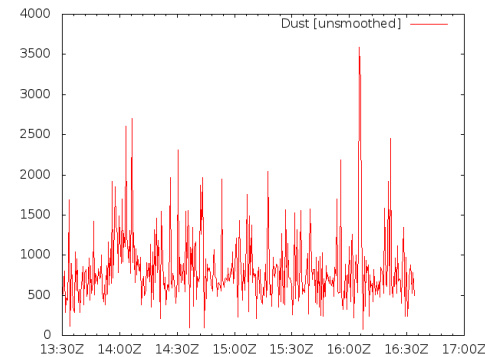
Moving Forward

- Mar-May 2015: Install 3-4 prototype sensors, sending observations to the web
  - Enable alerts to NWS, ADOT, Pinal & Maricopa sheriffs

- May-Jul 2015: Work with partners to fund more sensors and deploy
  - Example: ADOT's research proposal

- Also:
  - experiment with APRS (amateur radio technology) to send observations to the "cloud" when Internet is not readily available

  - Experiment with small solar panels for instances when power is not readily available

  - Inclusion of low-cost Raspberry Pi webcam (~$25)?

References

- Some Arduino/Raspberry Pi air quality projects
  - Sensor deconstruction: http://takingspace.org/wp-content/uploads/ShinyeiPPD42NS_Deconstruction_TracyAllen.pdf
  - Taking Space/Sonoma article: http://www.takingspace.org/make-your-own-aircasting-particle-monitor/
  - Chris Nafis: http://www.howmuchsnow.com/arduino/airquality/grovedust/
  - Irq5io: http://irq5.io/2013/07/24/testing-the-shinyei-ppd42ns/
  - Sensor calibration: http://indiaairquality.com/2014/09/14/calibrating-the-shinyei-ppd-sensors-part-1/
  - Beijing project: http://aqicn.org/sensor/shinyei/

- NWS/ADOT Dust storm workshops (Casa Grande, 2012, 2013, 2014)
  - http://www.wrh.noaa.gov/psr/dust/

- Dust storm videos
  - Mike Olbinski time lapse video, July 5, 2011: http://vimeo.com/26045314
  - Helicopter footage: https://www.youtube.com/watch?v=8W4Cx44XKZ4

- 2014 NWA Poster: http://files.nwas.org/presentations/nwa2014/NWA2014_P3.24_Waters.zip

Questions/Contact Info

Special Thanks to:

- Dan Leins, Phoenix NWS
- Nathaneal Burriss, ASU, Electrical Engineering
- Daniel Brilliant, ADOT
- Tim Dye, Sonoma Technology
- Support and offers to help with siting: AZ DPS, ADEQ, Pinal AQ, ADOT

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