GLOBE Surface Ozone Instrumentation: Evaluation, Improvements and Recommendations

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Presentation to Science Advisory Committee
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Margaret Pippin, Jessica Taylor, and Lin Chambers
NASA Langley GLOBE Atmosphere Training Center of Excellence

Margaret Pippin
Surface Ozone Scientist (since 2002)
Master Trainer

Lin Chambers
Contrails Protocol, PI (since 2002)
Master Trainer

Jessica Taylor
Master Trainer
Atmosphere Protocols
(since 2000)

NASA student interns
Tomer Cohen – LARSS 2004
Ashley Mertens – USRP 2006 & LARSS 2007
Cory Scott – LARSS 2007 & 2008
Alec Weisman – USRP 2012 & 2013
Charles (Stephen) Haggard – LARSS 2013
Surface Ozone Team testing of Zikua/Test Card System

Test cards
- colorimetric method; tin(II) diphenylcarbazide
- refined recipe for linearity of response
  and increased sensitivity at low ozone concentrations
- extensive laboratory and ambient air testing for T and RH dependence
- designed prototype inlet box for constant flow rates across test cards
- test card response with aging
- tested each batch of test cards before sending to schools through 2005

- observed manufacturing to correct procedure and for quality control issues

solution should be clear before applying to test cards

‘Pink’ solution was the cause of ‘bulls-eye’ effect on test cards
Operation of Zikua™ Optical Scanner

Exposed test card placed in slot of scanner

Diagram showing operation of the scanner:
- 540 nm LED
- Photodiode
- Voltage to Display
- Reflected light at 540 nm
- Color response on EcoBadge chemical strip
Spectral Reflectance as a Function of Ozone Concentration

Zikua LED emits light at ~540 nm

“White” Paper Calibration

Blank

23 ppb

54 ppb

77 ppb

145 ppb

Data from research Spectrophotometer
GLOBE Ozone Data at Jicín, CZ
Shows Evidence of Temperature Dependence

T ~ 18 °C

T ~ 0 °C
Calibration Tests Conducted at University of North Carolina Outdoor Smog Chamber Facility in July 2002

Facility originally built in 1973 by Harvey Jeffries and reconstructed in 1994 by Ken Sexton is 300 m³.
Chamber Studies to Determine Dependence of T and RH

Margaret Pippin and Linda Bush Set Up Chamber Testing Capability at NASA Langley in May 2004
Temperature Dependence of Calibration Curves

Fresh Test Cards

% Absorbance vs. Ozone (ppbv)

- Zikua T=70F
- Spectro 565nm T=70F
- Zikua T=91F
- Spectro 565nm T=91F
- Zikua T=115F
- Spectro 565nm T=115F

Legend:
- Red Circle: Zikua T=70F
- Blue Asterisk: Spectro 565nm T=70F
- Green Diamond: Zikua T=91F
- Green Circle: Spectro 565nm T=91F
- Purple Square: Zikua T=115F
- Pink Diamond: Spectro 565nm T=115F

8/22/2013
Studies Suggest Dependence on Humidity

Measurements in Outdoor Chamber
(44-51 ppb)

Measurements in Laboratory Jar
(77-89 ppb)
Ambient Air Testing for T and RH Dependence - 2006

Goals:
1) Determine calibration equation for GLOBE surface ozone instrument
2) Provide a correction factor for school ozone data on GLOBE website

Method:
Use ambient $O_3$, T, RH, and %ABS to derive statistical relationship

$$\%\text{ABS} = f(O_3, T, RH)$$

Summer 2006
>700 measurements collected
Results: Correcting GLOBE school ozone data

Regression equation
\[
\text{ABS} = \beta_0 + \beta_1 (Oz - \mu_{Oz}) + \beta_2 (T - \mu_T) + \beta_3 (Rh - \mu_{Rh})
+ \beta_{13} (Oz - \mu_{Oz}) (Rh - \mu_{Rh})
\]

Data reduction equation
\[
Oz = \mu_{Oz} + (\text{ABS} - \beta_1 - \beta_2 (T - \mu_T) - \beta_3 (Rh - \mu_{Rh})) / (\beta_1 + \beta_{13} (Rh - \mu_{Rh}))
\]
Surface Ozone Team testing of Zikua/test card system

Zikua

- calibration curve coded in chip has math errors
- corrected poor calibration coding and made recommendations to Vistanomics however recommendations were never implemented
- determined how to ‘back-out’ absorbances from zikua readings and then correct using derived statistical equation
- made changes to chip so they are programmable with our own calibration equation

Vistanomics Calibration Table for Zikua with default 135
Issues and Recommendations

Zikua/test card system
- when QC’ed, test cards can produce reliable long term trends
- however surface ozone team is no longer testing cards
- Vistanomics has changed test card manufacturer multiple times

- test cards can be made in a high school chemistry class
- use correction factor for zikua readings

- Vistanomics has not been willing to make improvements
- recommend phasing in new instrument with updated technology
Evaluation of Prototype Ozone Sensor - 2008

Miniature Ozone Sensor (MOS)
Tungsten oxide semiconductor sensor
Operates continuously with a data logger
Instantaneous measurements at specified intervals, (1 min, 5 min, etc.)

On loan from PAX Analytics, Inc

Developed at Smith College under an NSF grant
- Joyce Cheung (student)
- Paul Voss
- Thomas Hartley
- David Greenberg
Potential Ozone Sensor for GLOBE - Aeroqual ozone sensor

Aeroqual ozone sensor

- Tungsten oxide semiconductor sensor
- Operates continuously with a data logger
- Instantaneous measurements at specified intervals, (1 min, 5 min, etc.)
- cost ~$800 - $1200

Inter-comparison studies summer 2013

Aeroqual compares well with VA DEQ air monitoring data at CAPABLE site

http://www.ozonesolutions.com
Instrument testing in progress

Aeroqual testing with and without inlet box
* Aeroqual ozone sensor head must be calibrated in inlet box

Coincident measurements show importance of calibration
Sensor head received from vendor not calibrated in inlet box
Instrument testing in progress

Modifications to inlet box
- removed screens at inlet tube entrance
  (well known that airflow over metal causes losses – research-grade ozone instruments use teflon fittings rather than stainless steel)

inlet wall-losses not as great with screens removed

![Ozone concentration chart](image.png)
Issues and Recommendations for Aeroqual instrument

- Need to test a sensor that has been calibrated for use in the inlet box
- issues with battery life - rechargeable but instrument must remain on to charge
- issues with warm-up time before measurements are valid
- odd data dropouts; possibly due to serial to USB connector for data download
  (experienced similar issues with prototype instrument;
  it is known that certain brands of connectors perform better than others)

Aeroqual ozone instrument is very promising as an alternate GLOBE instrument

- sensor technology is being further developed and NASA research scientists are using this instrument and similar instruments for TEMPO & DISCOVER-AQ missions
- EPA is also testing Aeroqual for use in citizen scientist projects
- NASA and EPA are collaborating and sharing results on Aeroqual tests and findings