

Tropospheric Emissions:  
Monitoring of Pollution



# TEMPO Student Collaboration/Public Engagement Update

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Smithsonian



Hourly Measurement of Pollution

60 minutes

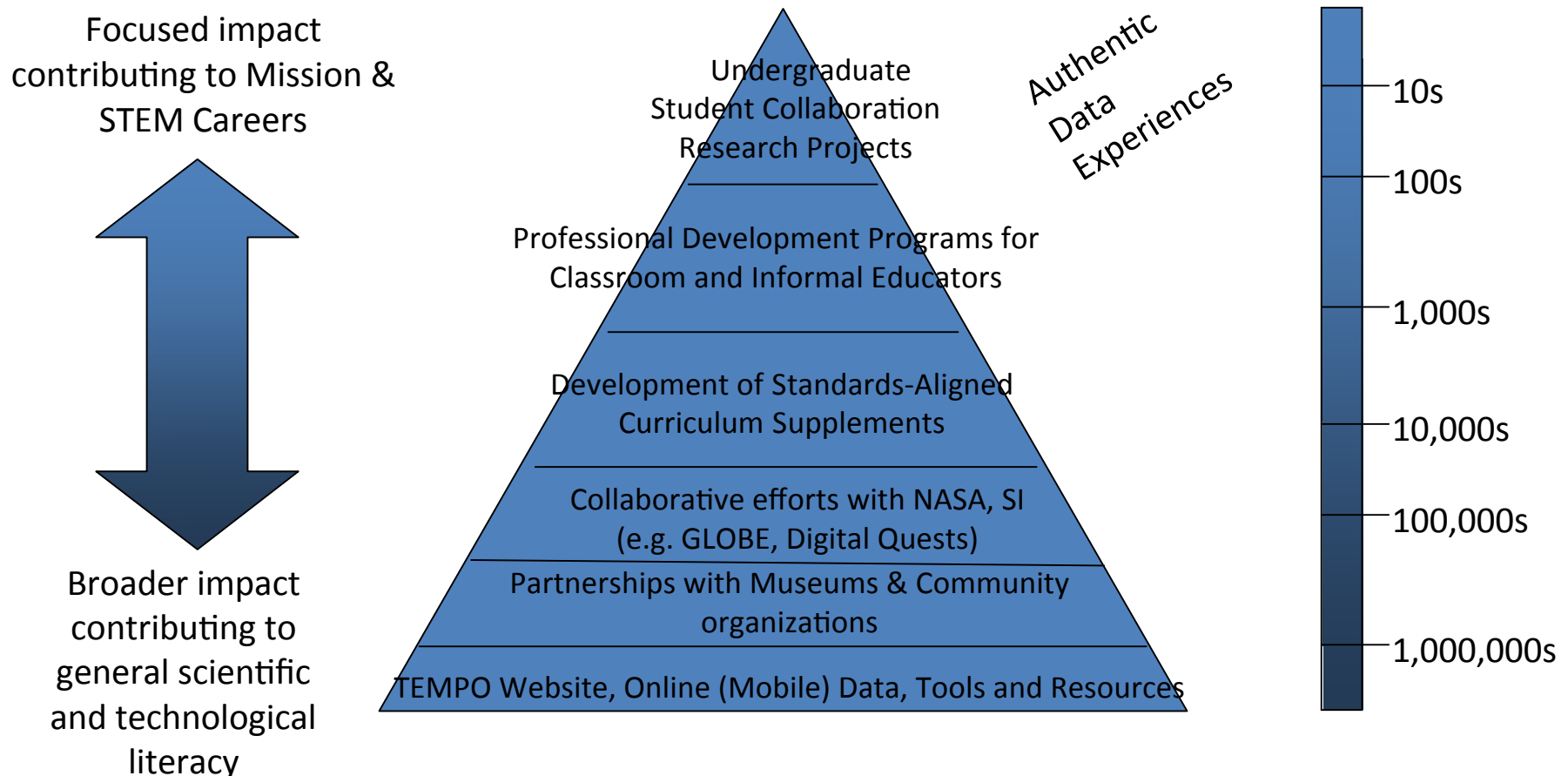
[www.nasa.gov](http://www.nasa.gov)



# Program overview-Impact



- Together, the TEMPO Student Collaboration and Public Engagement programs provide a progression of AQ-related authentic research experiences for different audiences, supporting NASA's STEM "pipeline" concept.





# TEMPO SC – Objectives & Outcomes



**GOAL:** Engage a diverse network of students and universities in TEMPO experimental validation and NASA air quality research during TEMPO mission

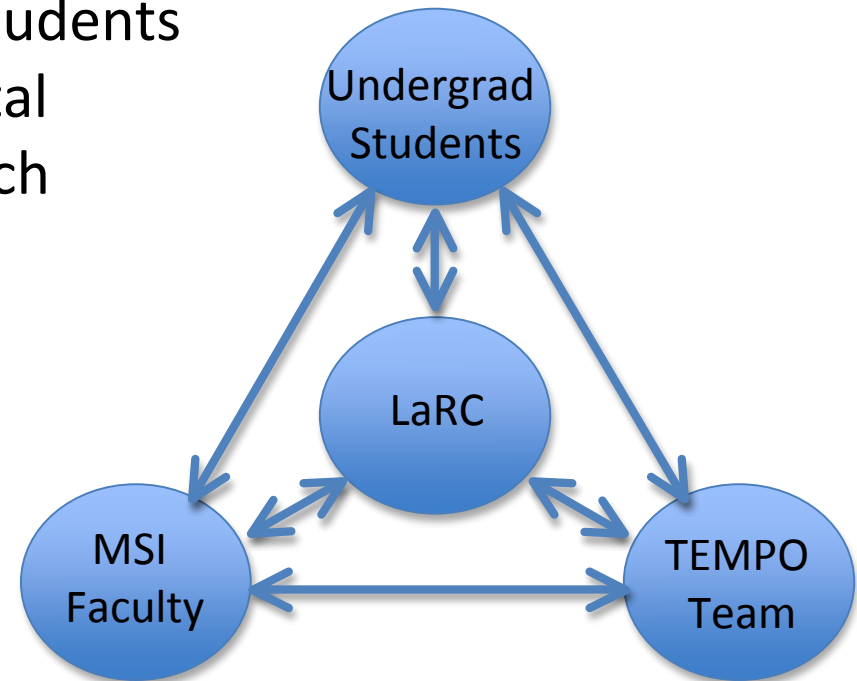
## OUTCOMES:

### Undergraduate Students

- Develop increased confidence and skills in scientific problem solving
- Pursue further education and/or employment in STEM

### MSI Faculty

- Strengthen research capabilities within MSI
- Establish collaborations with NASA and TEMPO scientists



### TEMPO Scientists

- Build collaborations with MSI faculty
- Develop pool of potential graduate students already engaged in TEMPO science





# Student Collaboration – Phase 1



## Instrument Evaluation & Experimental Design

### Sharing of Results

#### What:

Small Sensor Ambient Measurements & Intercomparisons

**Where:** LaRC & MSI's

**Who:** Undergrad Students & MSI faculty

2014 AEROSOL

2015 OZONE

2016\* NO2

2017\* UBV/other

#### What:

Small Sensor Laboratory & Ambient Characterization

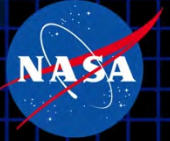
**Where:** EPA & TEMPO team institutions

**Who:** TEMPO team

(\*Dates to be re-phased according to launch)



# SC Exploratory Validation Network



**When:** 2018, 2019, 2020\*

**What:** 1) use selected small sensors determined from laboratory and ambient testing,  
2) multi-measurement experimental design,  
3) long-term data record

**Who:** Undergrad Students & MSI faculty, and TEMPO team members

**Where:** LaRC & MSI's and TEMPO institutions

Value added

TEMPO Federated Network  
of Validation Sites

(\*Dates to be re-phased according to launch)

## Intercomparison of GLOBE, CALITOO, and SHADE Sun Photometers with AERONET



### Summer 2014 NASA Student Interns

Stephen Haggard – Georgia Institute of Technology

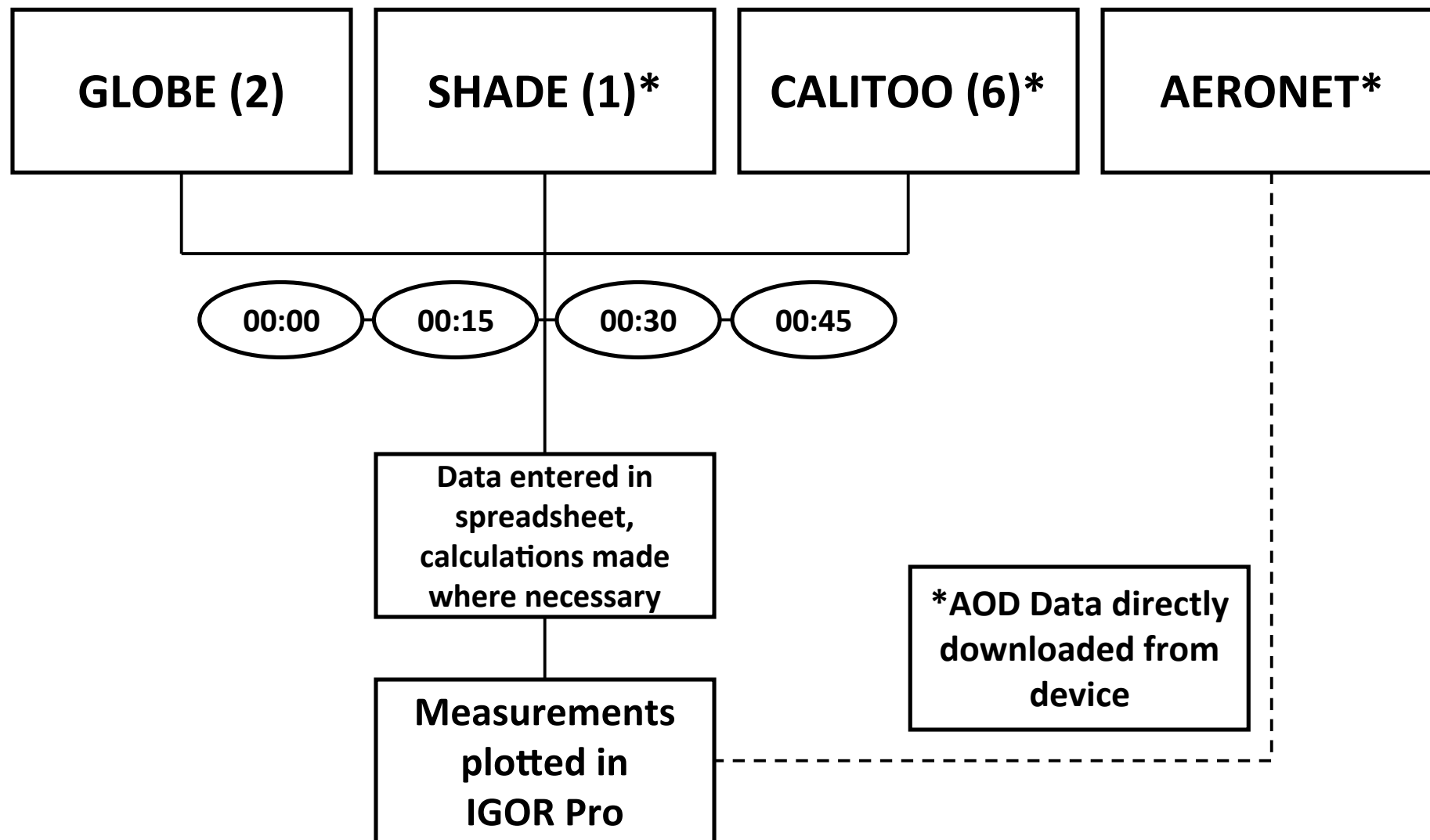
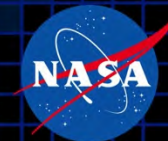
Cara Moulton – Sitting Bull College

Christopher Atkinson – Norfolk State University

Robert Bujosa – The College of William & Mary



# Summary of Data Acquisition





# Breakdown of Amount of Data



**40 Total Days of Opportunity**  
**9 Handheld Instruments**

**18 Days of Clear Conditions**  
**13,648 Total Trials**  
**(for All Handheld Instruments)**

**4534 Total Data Points\***

**946 Data Point**  
**Times Align<sup>+</sup>**

**9 Days of AERONET Operation**

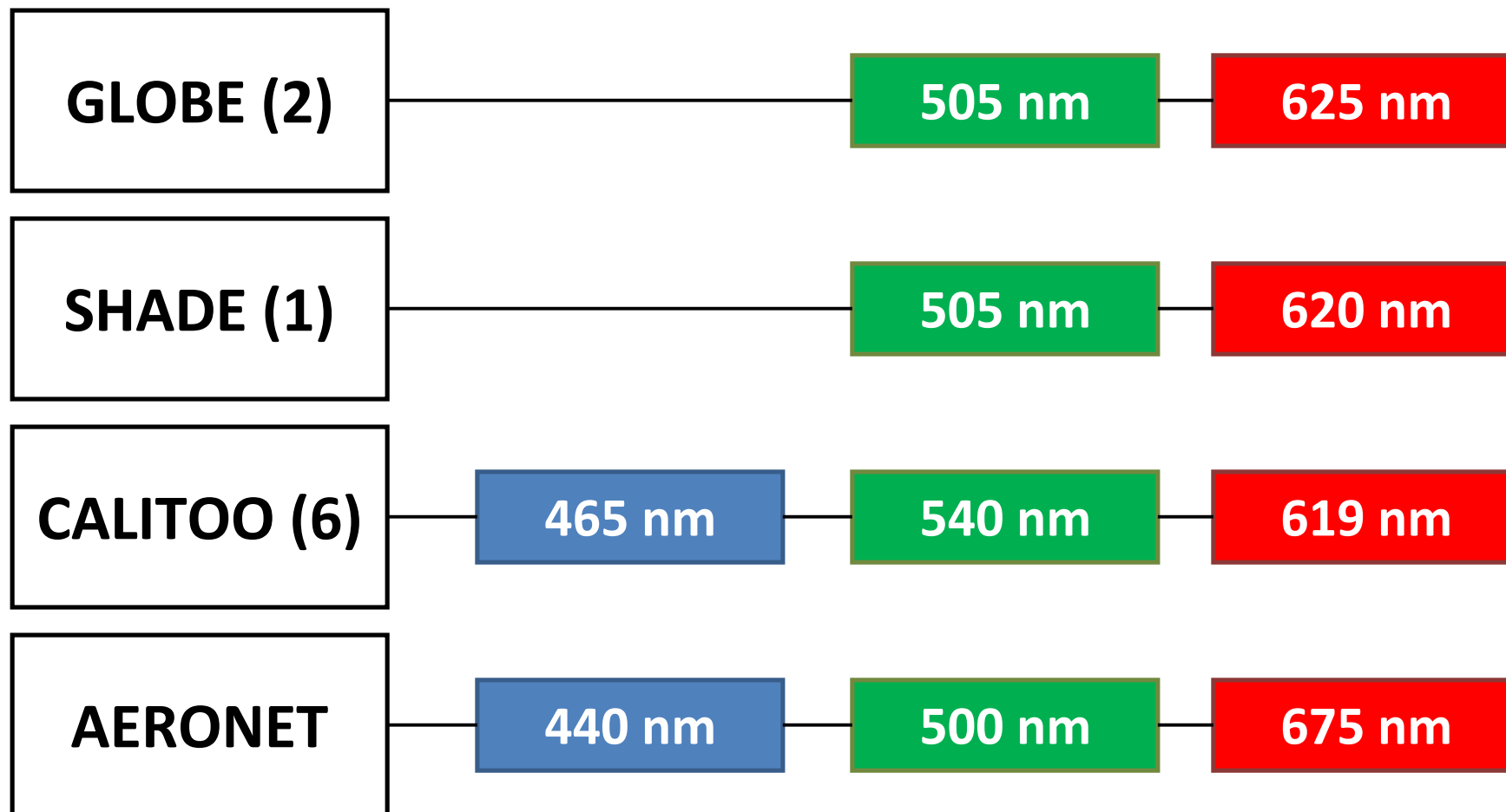
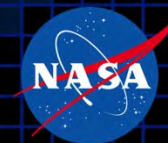
**\*1 Data Point = Average of 3 Trials**

**<sup>+</sup>Within a 12:00 to 15:00 UTC Range**





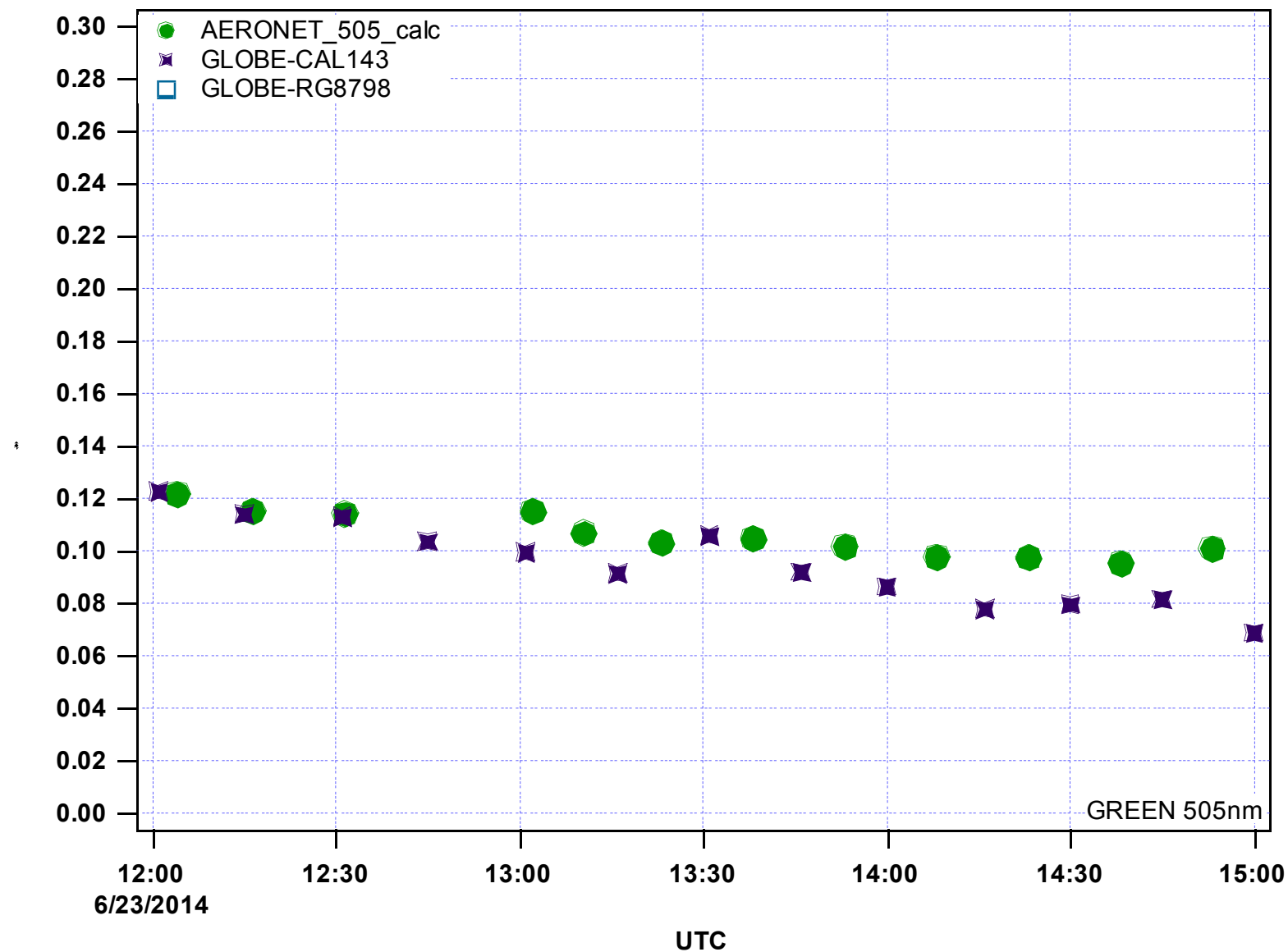
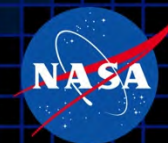
# Instrument Wavelengths



Use AERONET angstrom exponent to interpolate to GLOBE, SHADE, or Calitoo wavelengths for direct comparison

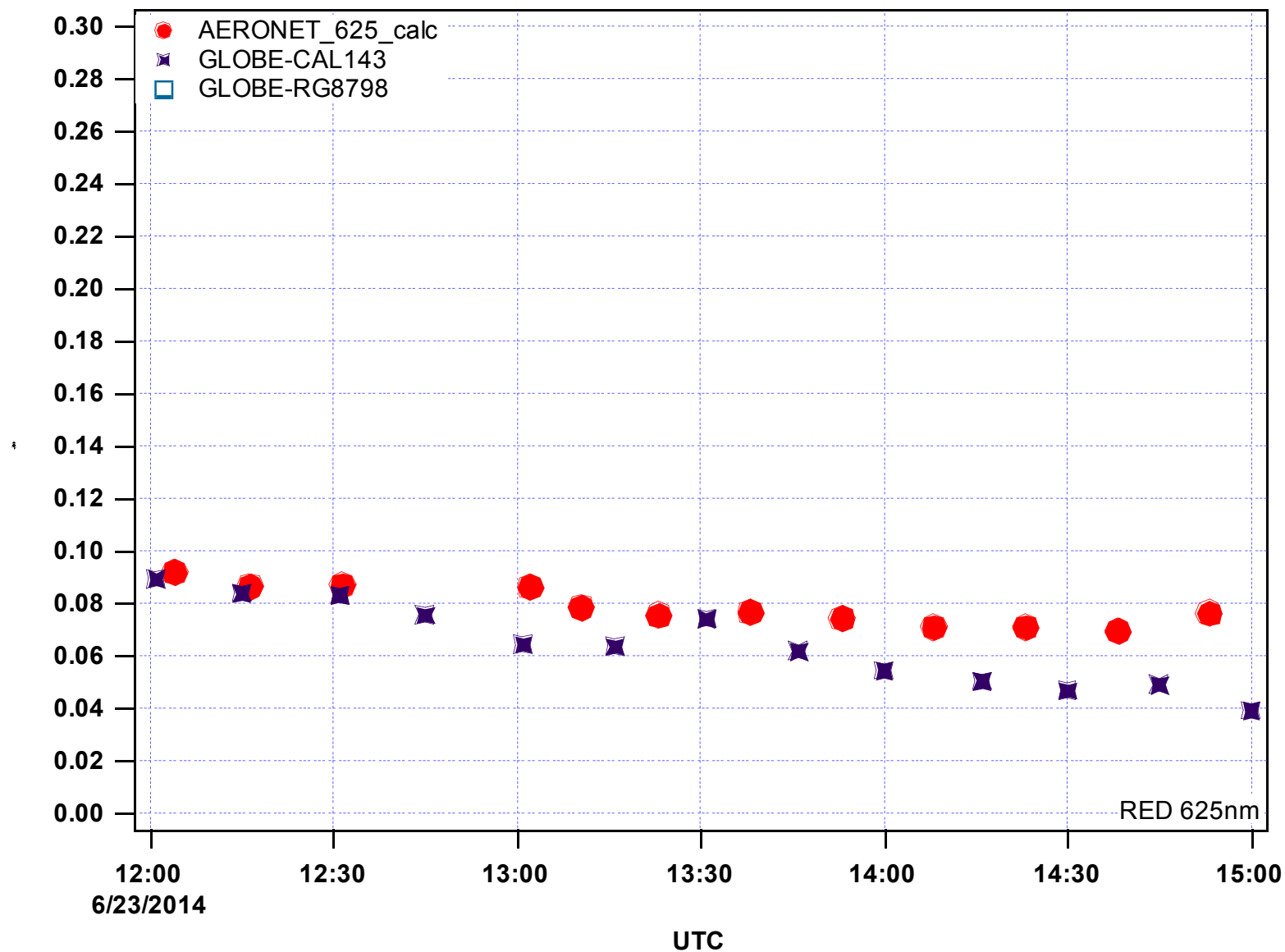
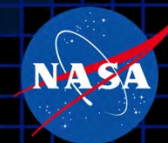


# Clear Day – GLOBE (505nm)



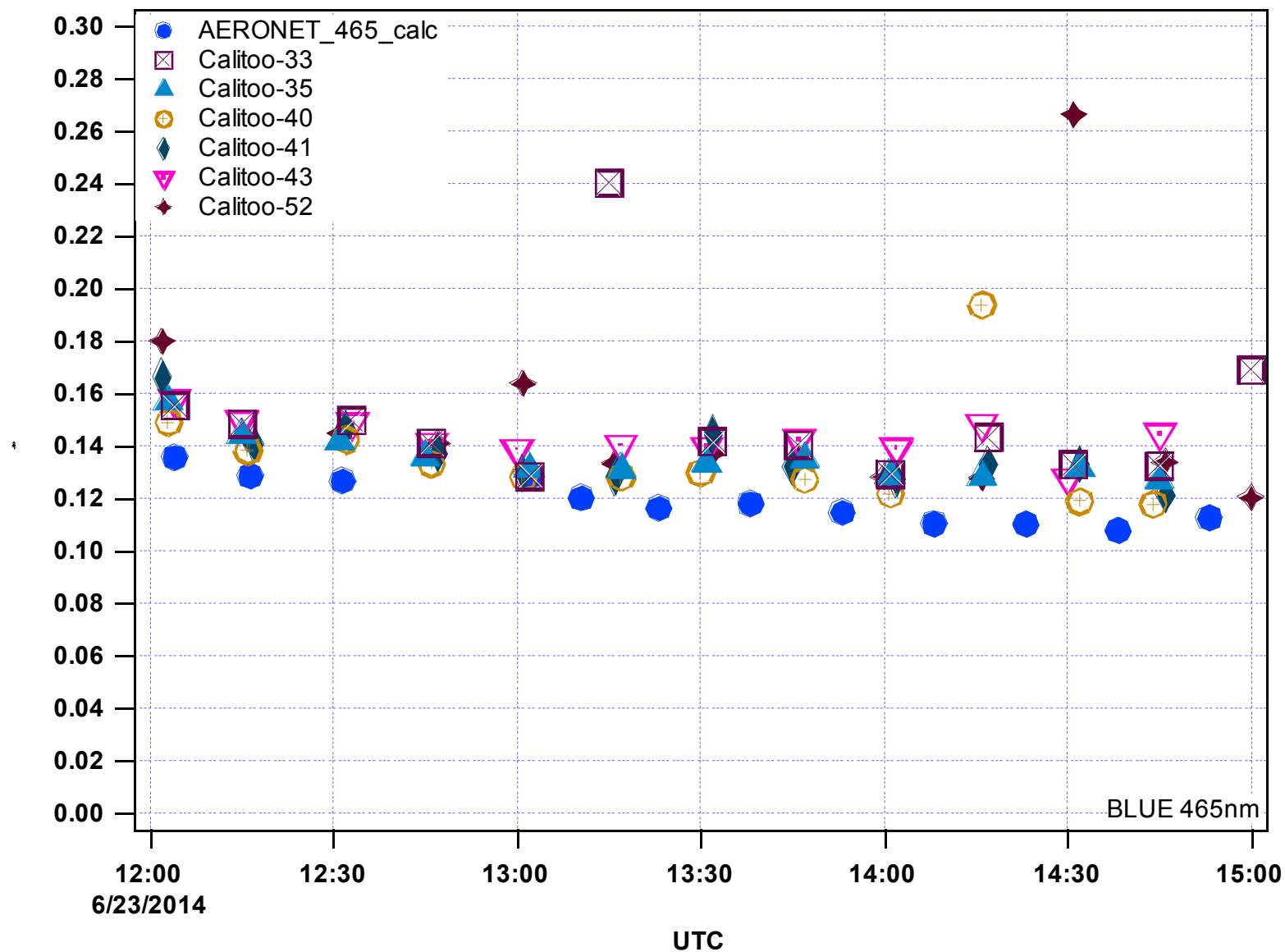
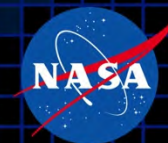


# Clear Day – GLOBE (625nm)





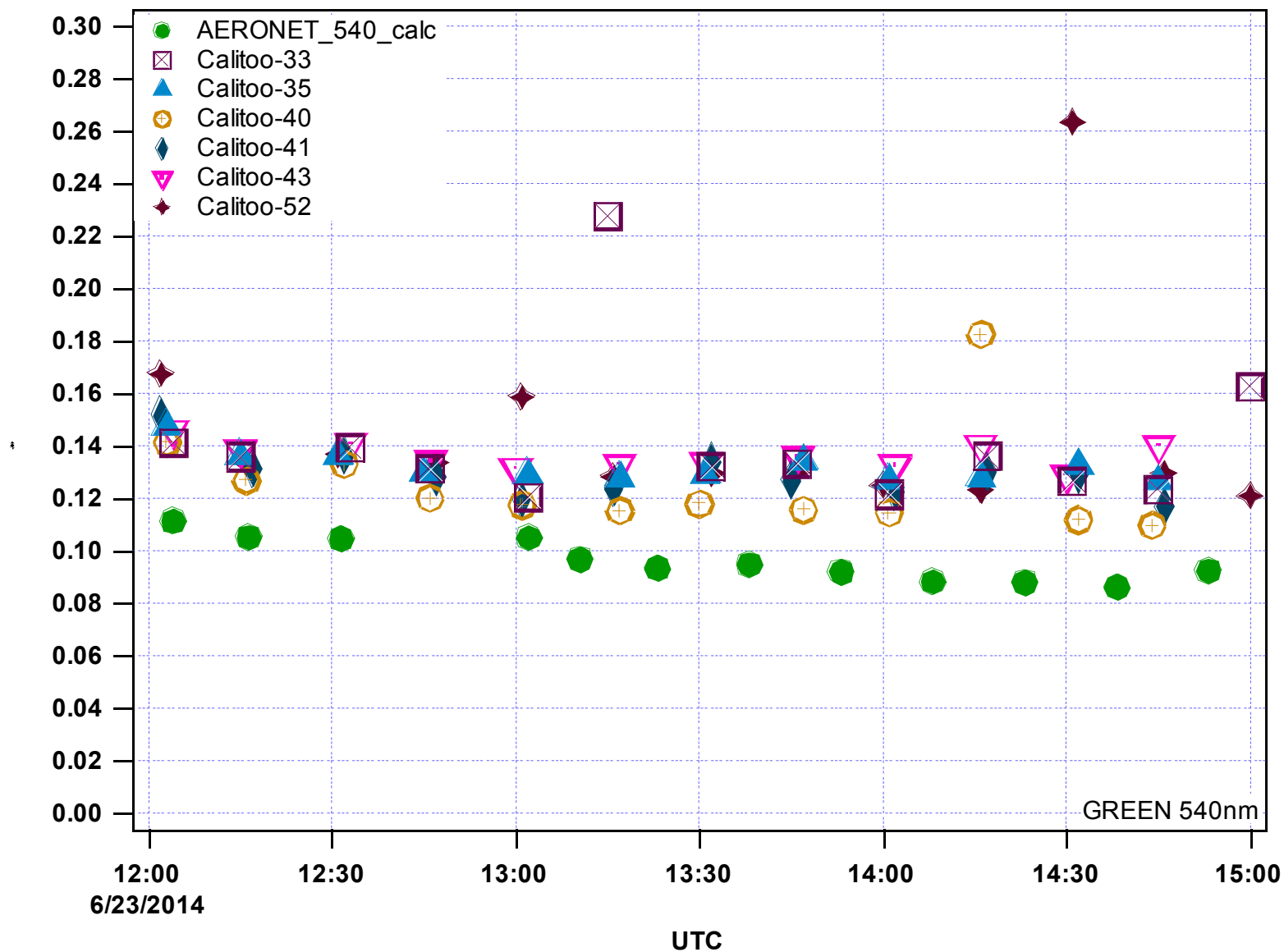
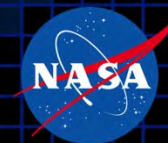
# Clear Day – Calitoo (465nm)





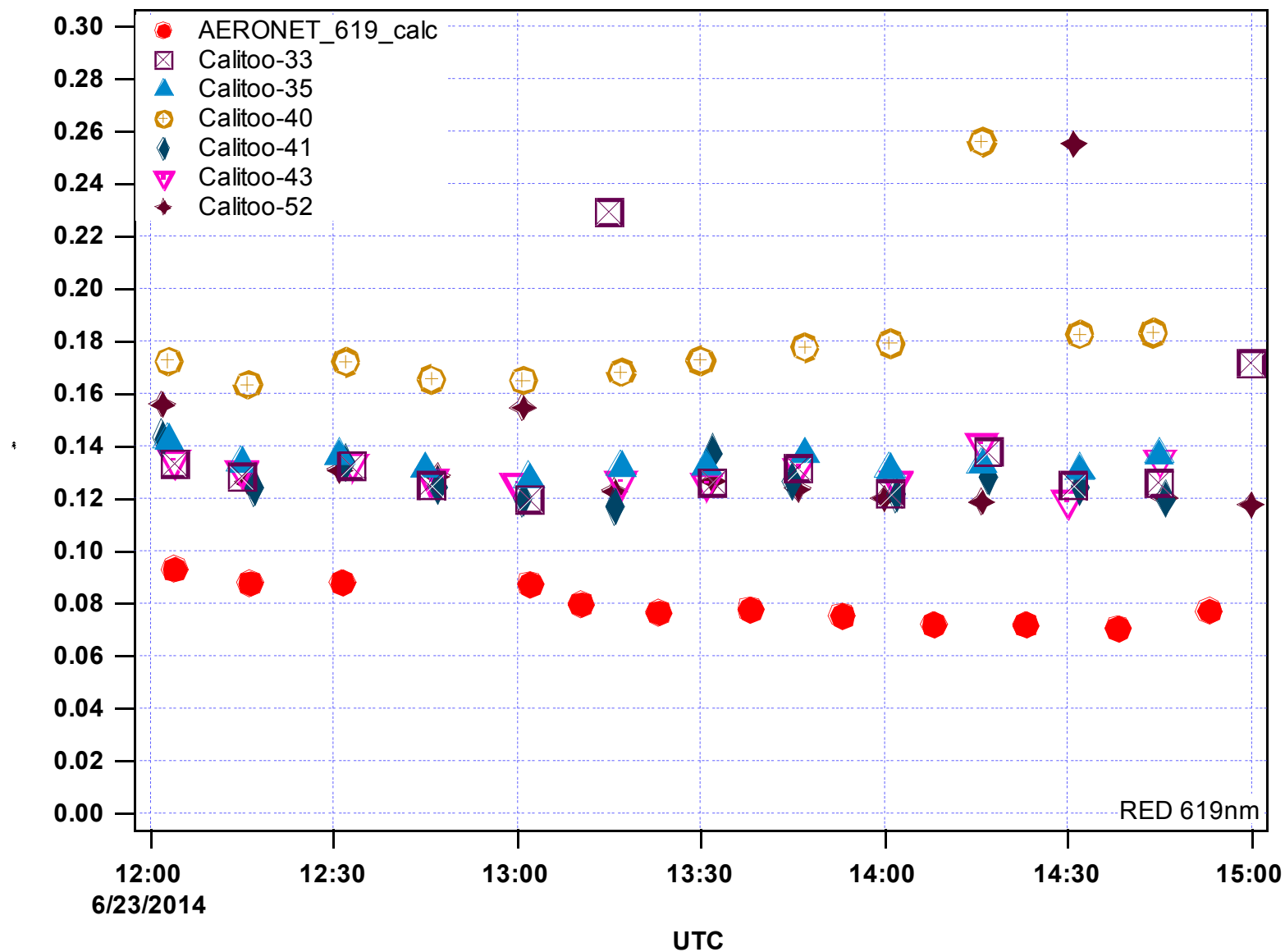
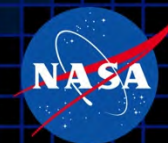


# Clear Day – Calitoo (540nm)



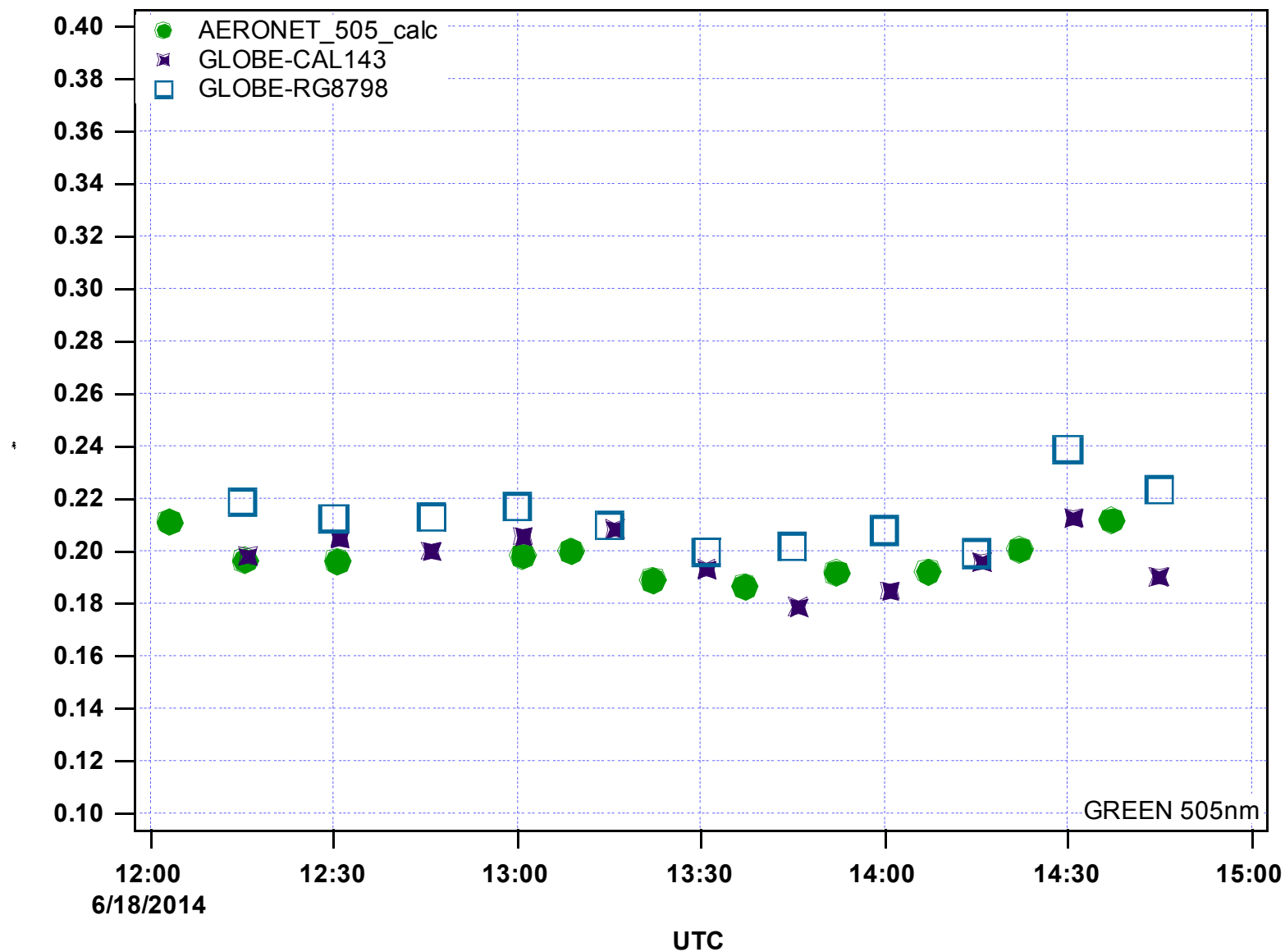
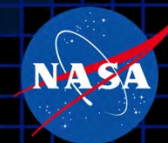


# Clear Day – Calitoo (619nm)



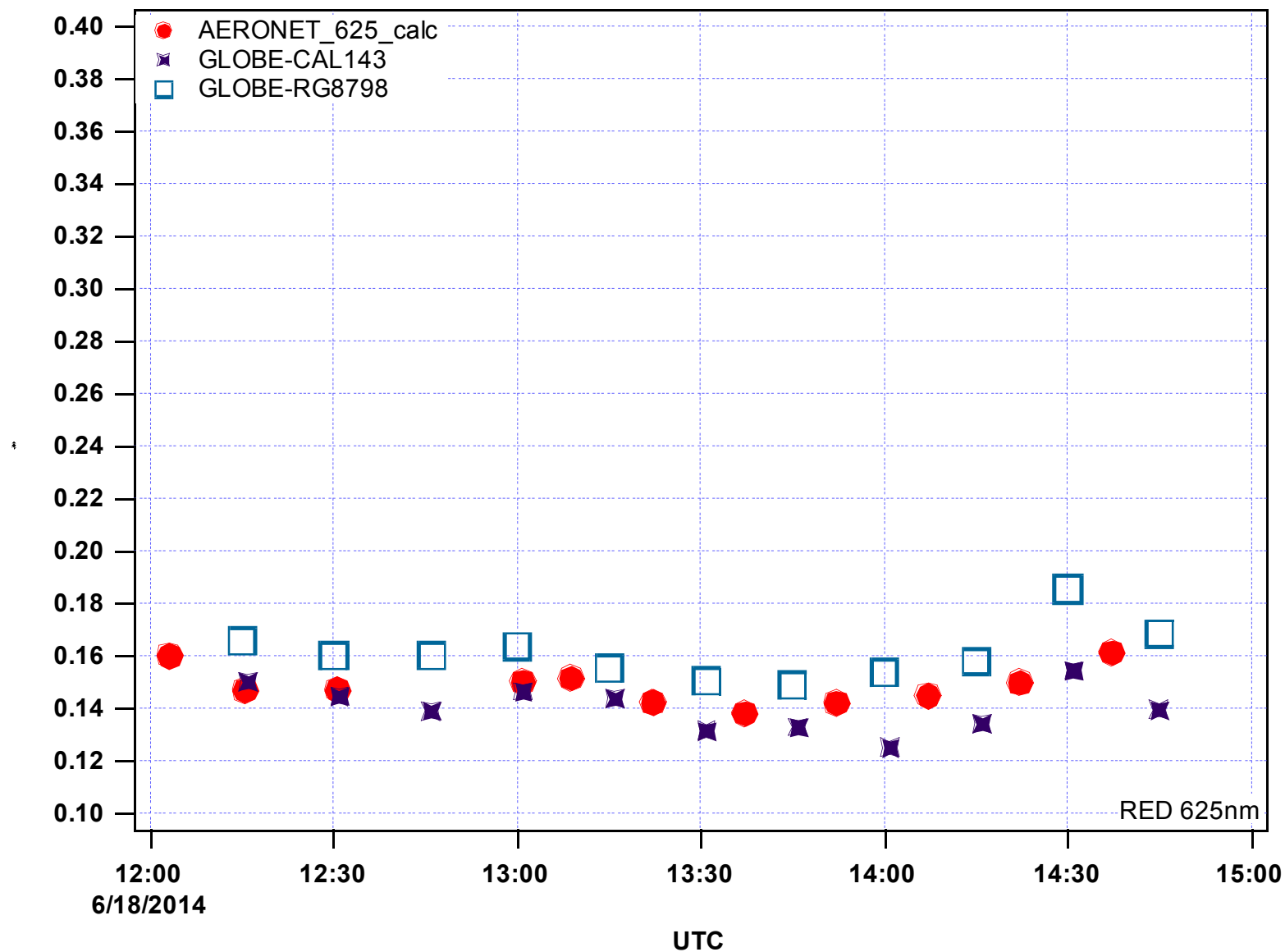
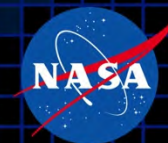


# Somewhat Hazy Day – GLOBE (505nm)





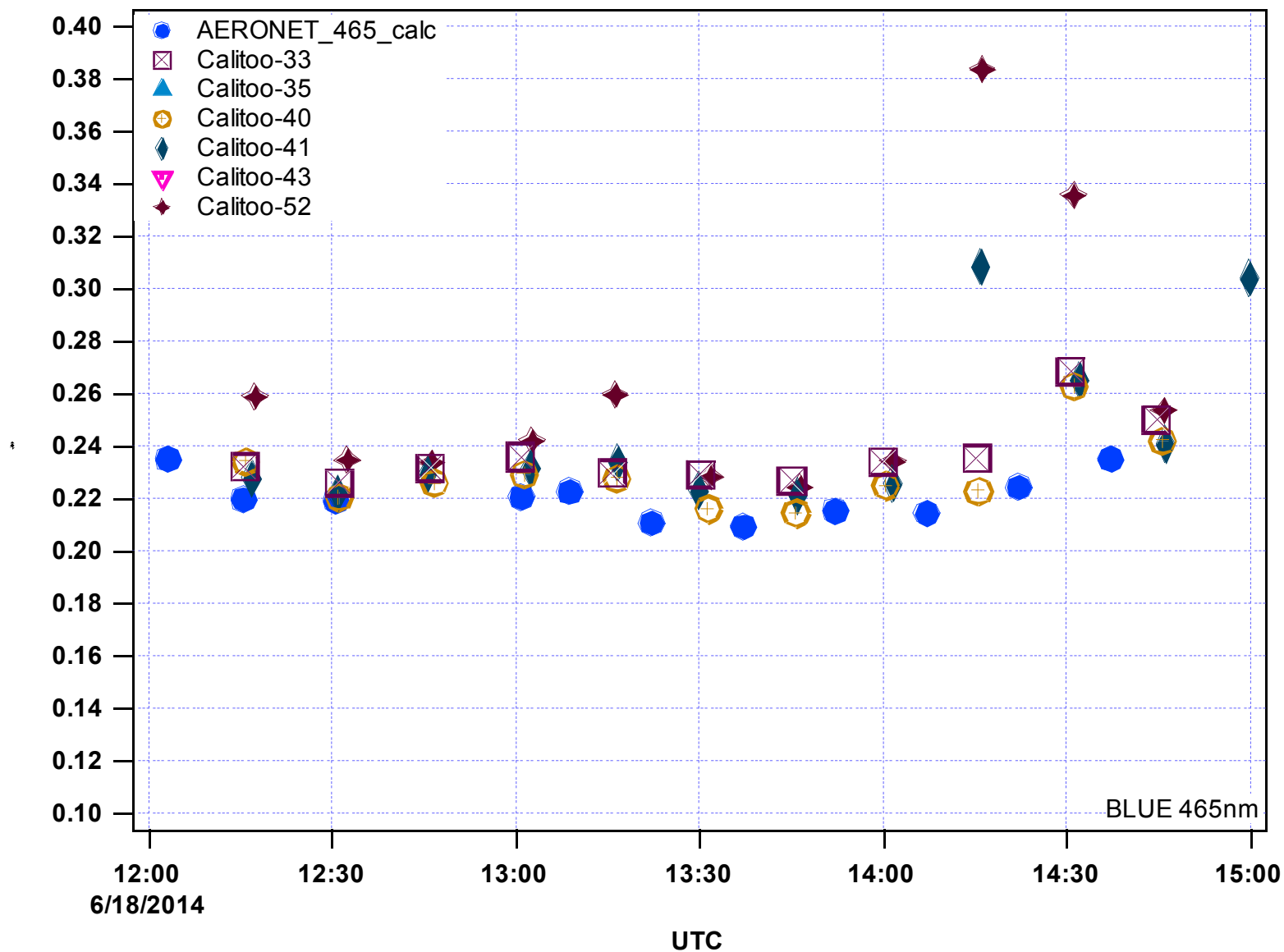
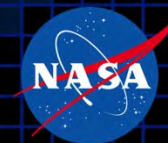
# Somewhat Hazy Day – GLOBE (625nm)





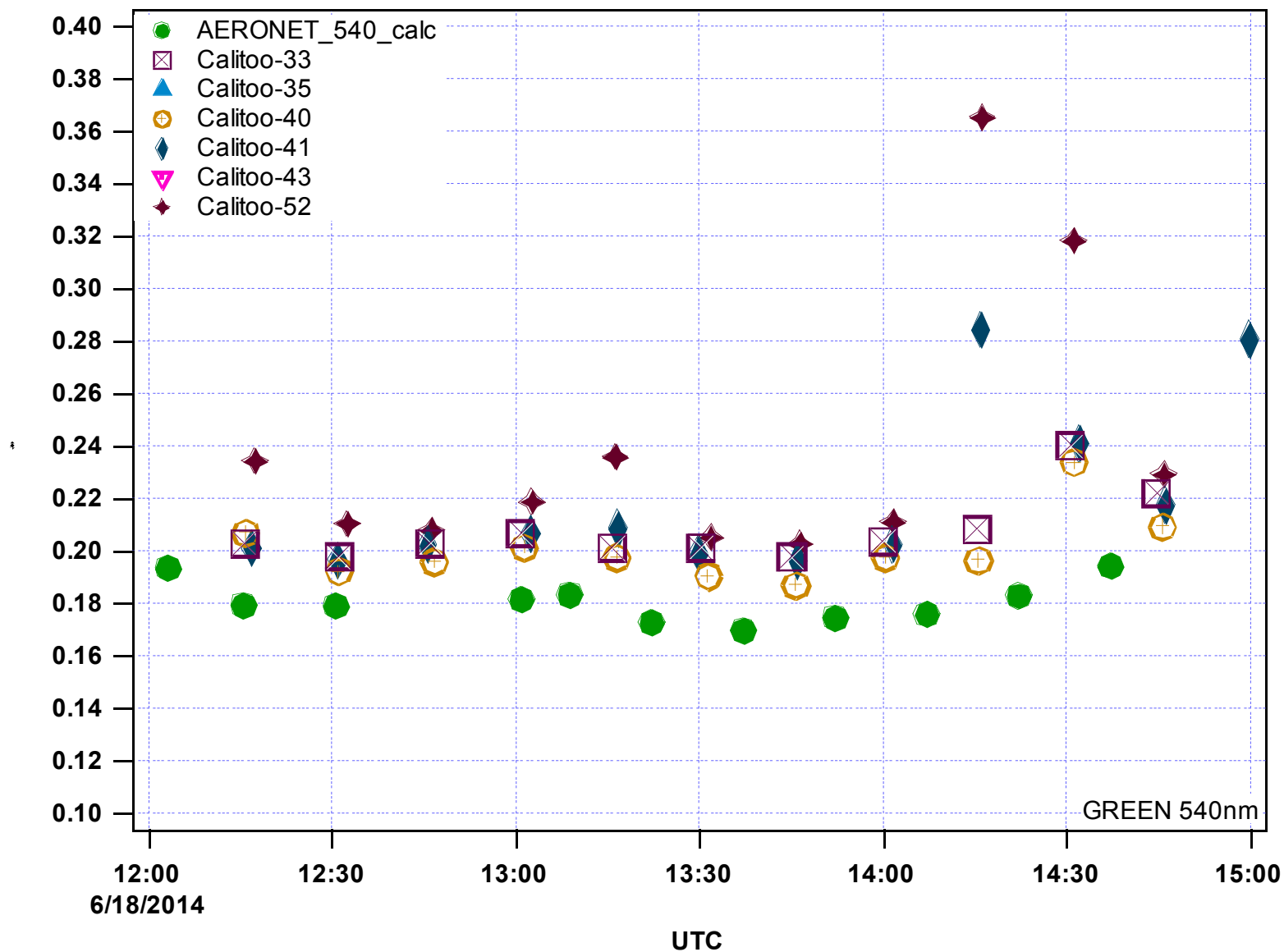
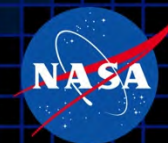


## Somewhat Hazy Day – Calitoo (465nm)



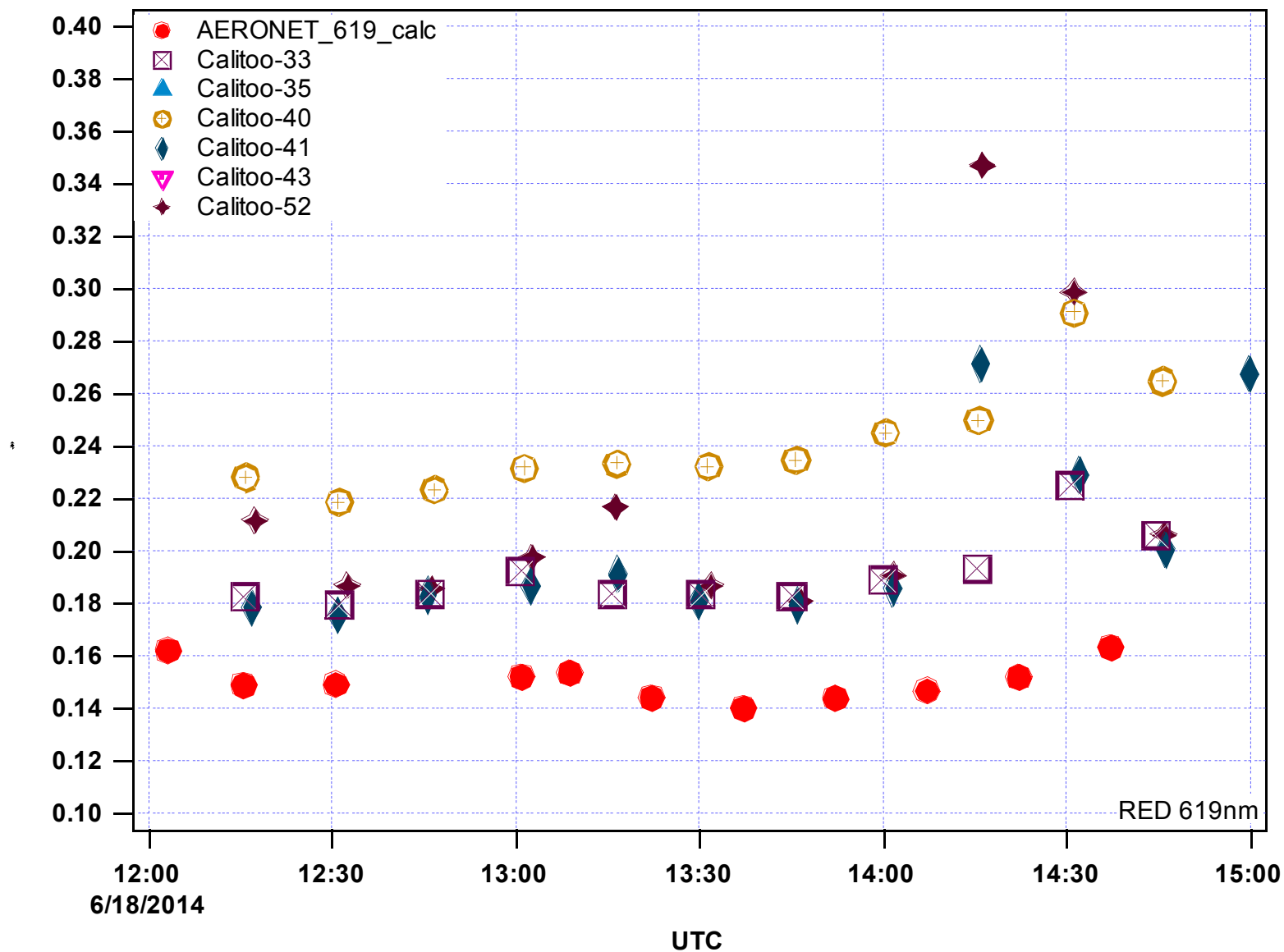
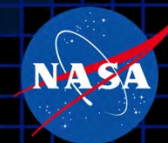


## Somewhat Hazy Day – Calitoo (540nm)



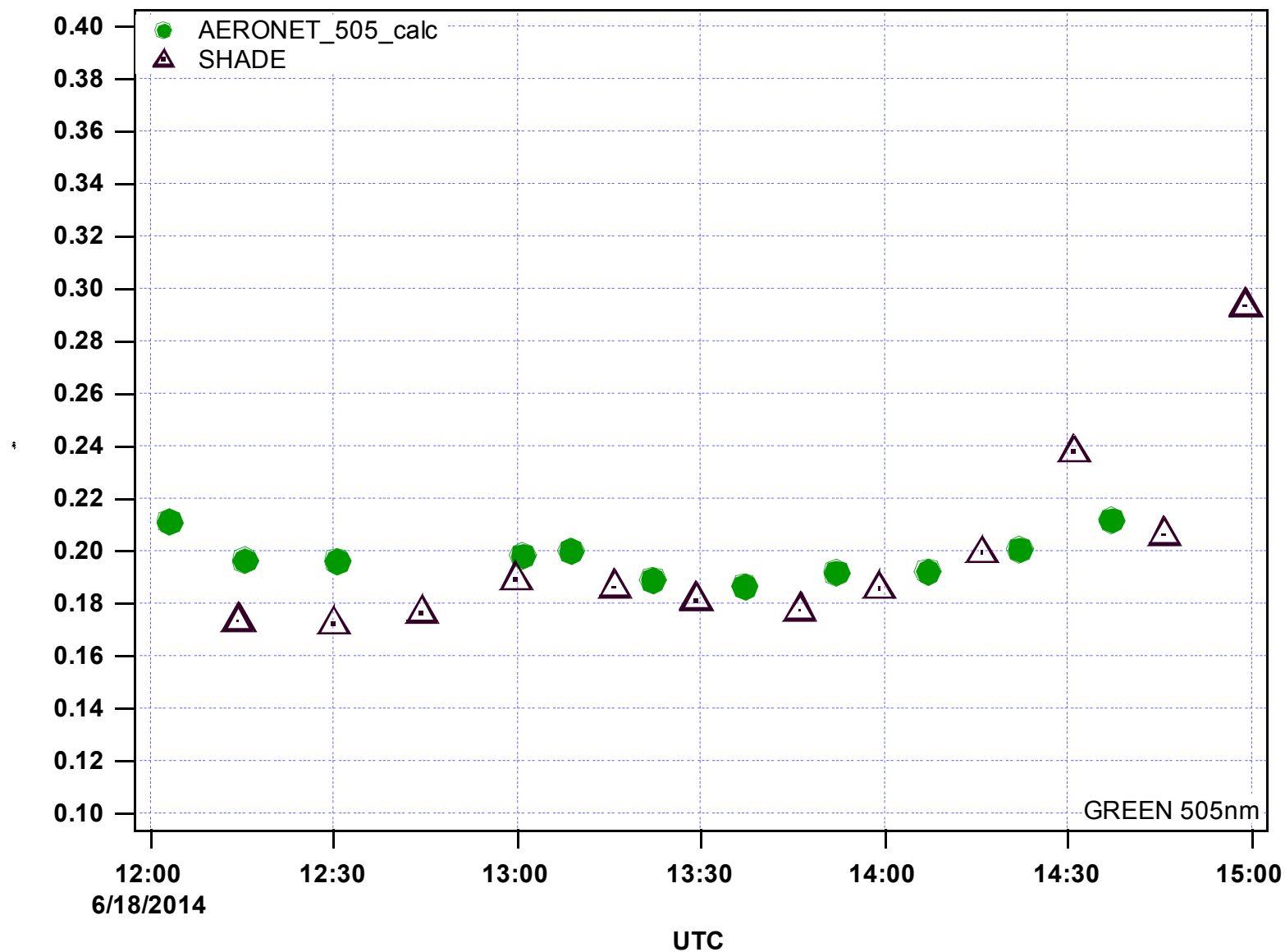
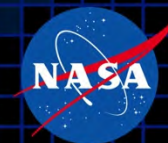


## Somewhat Hazy Day – Calitoo (619nm)





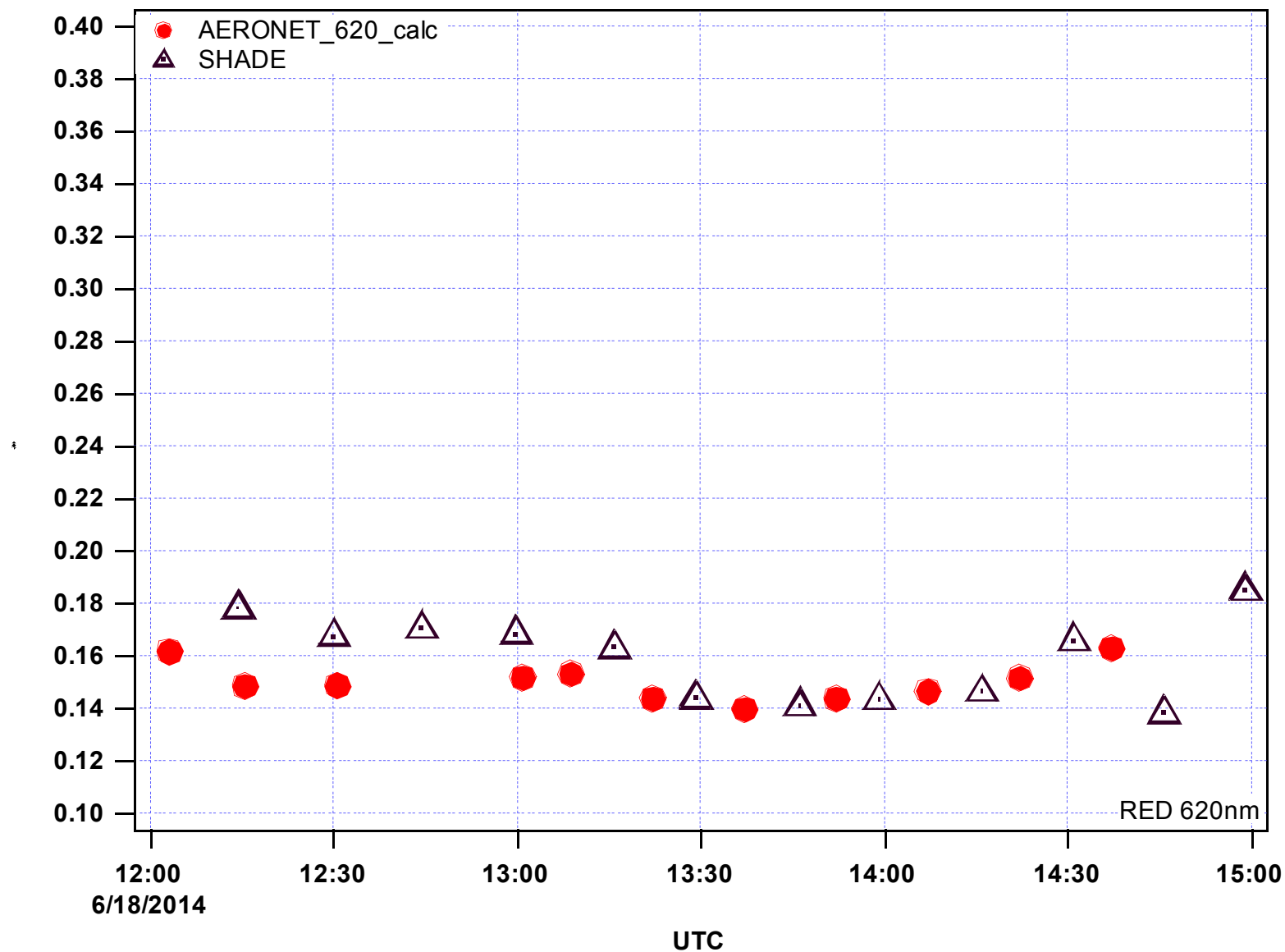
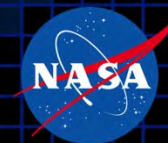
## Somewhat Hazy Day – SHADE (505nm)







# Somewhat Hazy Day – SHADE (620nm)





# Summary of Instrument Results



Instruments Evaluated for ***Usability, Data Quality, and Data Download***

## **Findings discussed with instrument scientists and vendors**

- **GLOBE** instrument - Institute for Earth Science Research and Education in US
- **Calitoo** – CNES and Tenum in France
- **SHADE** – GSFC and Monterrey Institute of Technology in Mexico

## **Vendor updates to instruments based on SC evaluation results**

- All Calitoos were recalled for re-calibration, currently in production for purchase
- SHADE - improvements made to software and instrument design, production to begin this summer

## **Based on Evaluation – Selected Instruments will be used for:**

- TEMPO SC Exploratory Validation Network
- GLOBE Student Science
- Citizen Science



## New Collaboration with MSI



### TEMPO team members collaborate with MSI on NASA Education Proposal

***Temporal and Spatial Variability of Air Quality: Merging Research, Environmental Technology, and Education on the Standing Rock Reservation***

Sitting Bull College, North Dakota  
PI – Joshua Mattes

Submitted to:

NASA's Minority University Research and Education Program (MUREP)  
Institutional Research Opportunity (MIRO)

\*Proposal was not selected for funding (no Tribal College was selected)

Will encourage PI to submit modified proposal to:  
NASA Earth Systems, Technology, and Energy Education for MUREP (**NASA ESTEEM**)



## SC Summer 2015 – O3 & NO2



### Student Collaboration Plan for Summer 2015

- Continue evaluation of aerosol instruments
- Begin evaluation of Ozone and NO2 instruments  
(2B Tech POM, Cairclip, Aeroqual)  
in collaboration with EPA and TEMPO team members

### Summer 2015 NASA Student Interns – begin June 1

Rachel Slank – University of Texas, El Paso

Zachary Fair – North Carolina State University

Pablo Sanchez – Miami Dade College

Abbey Rodjom – Ohio University

Blake Phillips – W.T. Woodson High School, Fairfax VA





# SC Connections to C/PE



## Ozone Bio-Indicator Garden

established Summer 2014 at Virginia Living Museum



### During Summer 2015

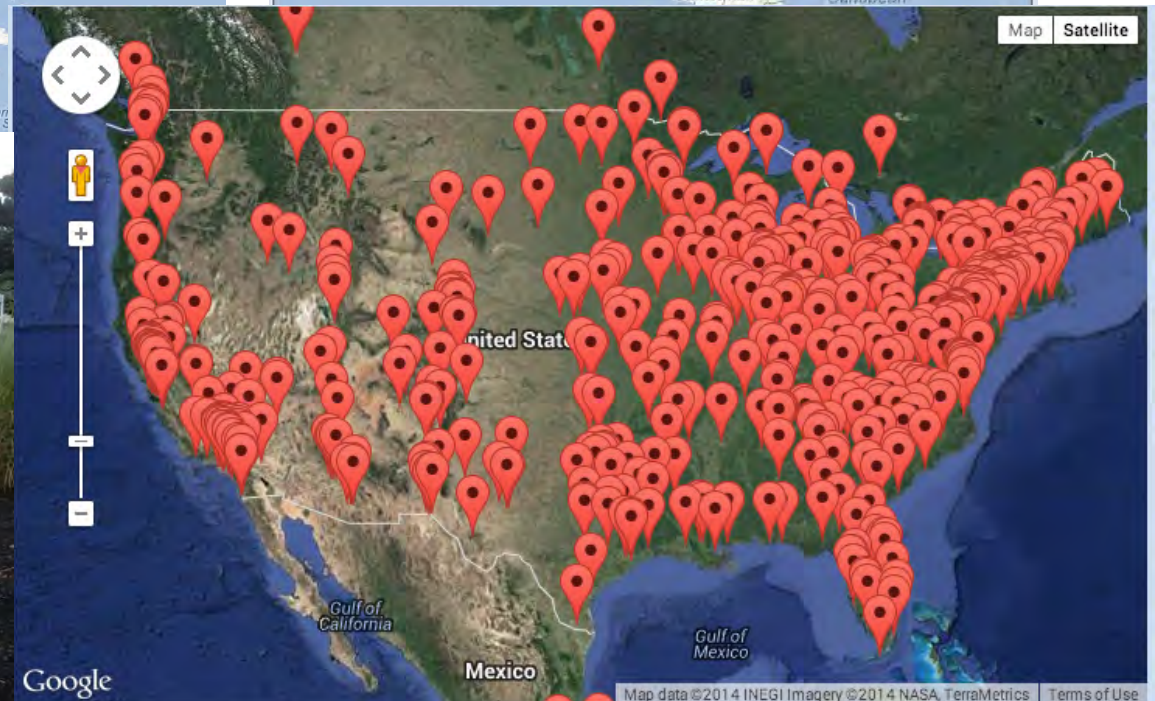
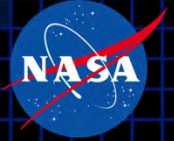
- SC student interns will quantify ozone-induced injury to plants (stippling on leaves) and correlate to ozone concentrations
- SC student interns will engage public about air quality and the TEMPO mission

Future Plans: include a TEMPO specific sign at the garden, install an ozone monitor, and formalize collaboration with VLM (Space Act Agreement)





# Museum Networks



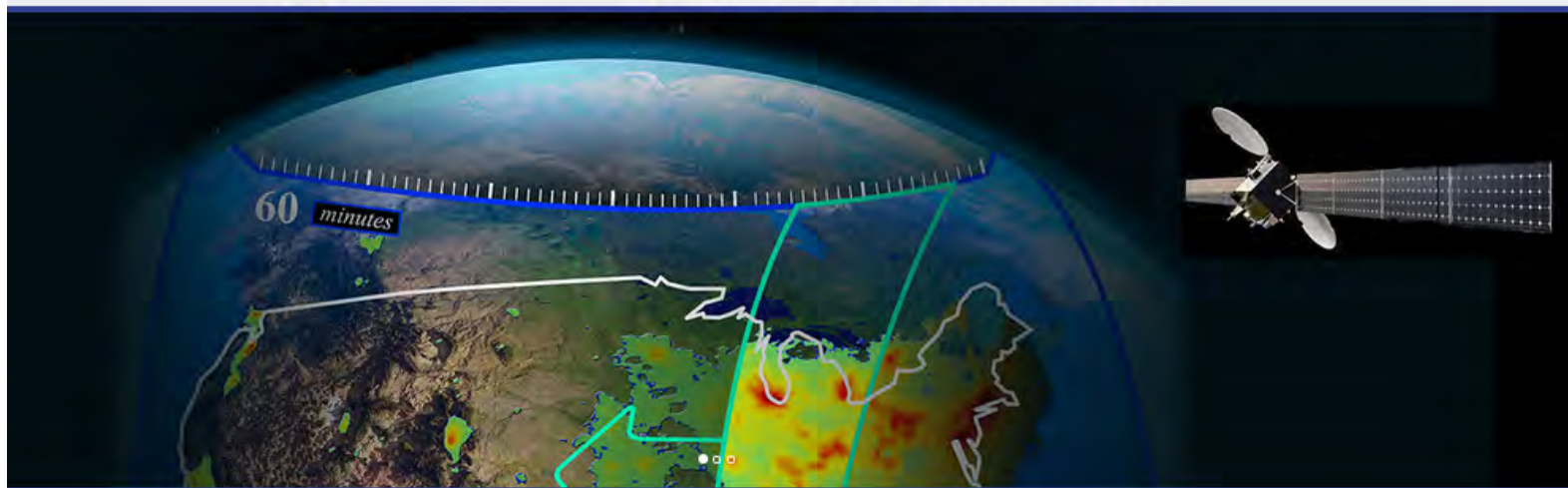




Tropospheric Emissions:  
Monitoring of Pollution



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## Welcome to TEMPO

### Mission Overview

NASA's first Earth Venture Instrument mission will measure pollution of North America, from Mexico City to the Canadian oil sands, and from the Atlantic to the Pacific hourly and at high spatial resolution. TEMPO observations are from the geostationary vantage point, flying on a telecommunications host spacecraft with the goal to launch in 2019.

[Learn More](#)

### TEMPO Instrument

The TEMPO instrument is a UV-visible spectrometer, and will be the first ever space-based instrument to monitor air pollutants hourly across the North American continent during daytime. It will collect high-resolution measurements of ozone, nitrogen dioxide and other pollutants, data which will revolutionize air quality forecasts.

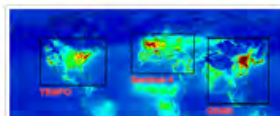
[Learn More](#)

### Latest News

**May 6, 2015 | TEMPO Pollution Monitoring Instrument Passes Critical NASA Review** It was confirmed by NASA's Science Mission Directorate to continue into Phase C of the project, in which the team completes the design that meets science and measurement requirements, fabricates the instrument, and develops the ground system.

[Learn More](#)

## Gallery







# BACKUP





## SUMMARY OF FINDINGS TO DATE



### **CALITOO (6 instruments):**

- Usability – nicely weighted in hand, but requires practice to get good measurements
  - Fairly simple operation; small field of view (aperture) makes it difficult to stabilize the alignment; some issues with manufacturing quality control.
- Data quality – some Calitoos at some wavelengths compare well
  - 1 of 6 Calitoo has distinct offset in data – possible calibration issue.
  - Measurements at green and red wavelengths biased high.
  - Data scatter could be due to the stabilization issues, calibration.
  - As wavelength increases - variability between instruments increases and accuracy decreases
  - Calitoo minimum AOD values not low enough – artificial detection limit?
- Data download – easy, but a few complications due to language and math practices (comma vs decimal point).



## SUMMARY OF FINDINGS TO DATE



### **GLOBE (2 instruments):**

- Usability – stable, easy to use, rugged, reasonably simple operation.
- Data quality – compares well with AERONET at both wavelengths within the stated uncertainties.
- Data “download” – record voltages and enter into website (less intuitive measurement but can be learned).

### **SHADE (1 instrument):**

- Usability: improvements in instrument construction since summer 2013; complex operation.
  - Small field of view (aperture) and off-centered design makes it difficult to stabilize the alignment and to make measurements.
  - Issues with manufacturing quality control and precision, plastic cover over apertures has scratches.
- Data quality – initially data collection resulted in good comparison with AERONET.
  - Instrument abruptly stopped providing reasonable data, alignment dot is no longer a circle possibly due to cracked part.
  - Pressure is unusually high (similar to summer 2013)
- Data download – initially no column headings; SHADE team added based on feedback. Date and time format unusable without decoder.