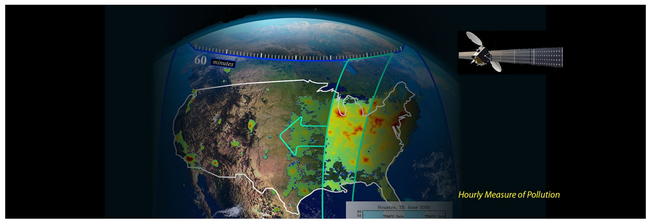
Plants, Pollution and Public Engagement with Atmospheric Chemistry: Sharing the TEMPO Story Through Ozone Garden Activities

Margaret R. Pippin[1], Gay Reilly[1], Emily Malick[2], Dan Summers[2], Mary E. Dussault[3], Erika Wright[3], John Skelly[4]

[1]NASA Langley Research Center, [2]Virginia Living Museum, [3]Smithsonian Astrophysical Observatory, [4]Pennsylvania State University

Monitoring Air Quality: TEMPO



What do a snap-bean plant and a future NASA satellite instrument named TEMPO have in common? They both increase our understanding of the quality of the air we breathe. Scientists, educators, and museum and student collaborators of the Tropospheric Emissions: Monitoring Pollution (TEMPO) instrument team are developing a program model to engage learners of all ages via public ozone garden exhibits and associated activities.

TEMPO, an ultraviolet and visible spectroscopy instrument due for launch on a geostationary host satellite between 2019 and 2021, will scan North America hourly to measure the major elements in the tropospheric ozone chemistry cycle. The TEMPO instrument project is led by the Smithsonian Astrophysical Observatory, with key partners including NASA Langley Research Center and Ball Aerospace. Once launched, TEMPO will provide high-resolution, near real-time measurements of changing air quality from Mexico City to the Canadian Oil Sands, and from the Atlantic to the Pacific.

Ozone
Ozone is a secondary pollutant that forms when primary pollutants, nitrogen oxides and hydrocarbons, react in the presence of sunlight.

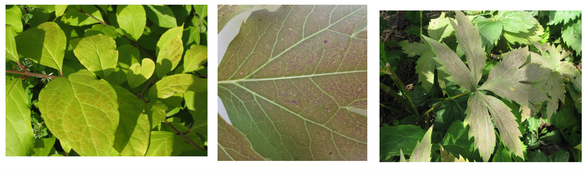
Why is ozone important?
Ozone in the stratosphere is often referred to as "good ozone" because it protects Earth from the sun's ultraviolet rays. Ozone in the troposphere, where we breathe, is often referred to as "bad ozone" because high levels of ozone near Earth's surface can have negative impacts on plant, animal, and human health.

Ozone Garden

A museum ozone garden exhibit affords an accessible way to understand air quality through a connection with nature, while providing a visual representation of the impact of ozone pollution on vegetation. Museum visitors are able to observe and record ozone induced foliar injury on selected ozone sensitive plants within the garden. Within the garden there are a combination of ozone sensitive and ozone tolerant plants so it is easy to view the differences of injury.

Indication of plant exposure to ozone
In ozone sensitive plants, ozone can cause stippling: small dots that appear on the upper side of the leaf, but not on the veins. The ozone tolerant plants show no symptoms.

Examples of ozone damage



Plants used for TEMPO ozone gardens include both agricultural as well as native plants. Native plants for future sites will need to be determined by region. The native plants in the garden are specifically sourced from The Shenandoah and The Great Smoky Mountains National Parks through special permits and agricultural plants from the USDA. These plants were chosen for their genetic sensitivity or tolerance to ozone.

Agricultural Plants	Sensitive	Tolerant
Solanum tuberosum **Potato**	*La Chipper*	*Superior*
Nicotiana tabacum **Cigar Wrapper Tobacco**	*Bel-W-3*	*Bel-B*
Phaseolus vulgaris **Snap Bean**	*S-156*	*R-331*

Ozone Sensitive Native Plants	
Common Milkweed	*Asclepias syriaca*
Cutleaf Coneflower	*Rudbeckia laciniata*
Black Cherry	*Prunus serotina*

For further information contact Margaret Pippin at m.pippin@nasa.gov

Virginia Living Museum as a Pilot Ozone Garden

A prototype ozone garden exhibit was established at the Virginia Living Museum (VLM) in partnership with NASA Langley, and serves as a site to formatively evaluate garden planting and exhibit display protocols, hands-on interpretive activities, and citizen science data collection.

The VLM is an informal science museum with an extensive collection of living plants and animals that are native to Virginia. The museum connects people to nature through educational experiences that promote conservation.

Audience
The VLM is an ideal site for piloting the garden and its corresponding activities due to the museum's wide variety of visitors. The majority of visitors consists of elementary school groups and families with children from 3 to 12 years old.

VLM Ozone Garden - Choosing a Successful Location
Since the ozone garden was established in 2012, it has moved locations on the museum grounds twice. The current location was selected to increase public visitation to the garden, to increase the area for plant growth, and to gain easier access to water.

Current Location of Ozone Garden at the VLM

Garden Signage

A GLOBE weather station is located near the garden. It contains a rain gauge and an air and soil thermometer that visitors can monitor, and add to their personal observations of the garden.

GLOBE Weather Station

Lessons Learned – Challenges in Developing a Thriving Garden

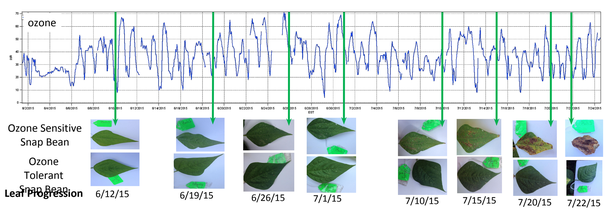
Location – A number of factors need to be taken into consideration when placing the garden: visitor flow, growing space, and access to water and sunlight.
Soil choice – The original soil was treated with nitrogen which created an imbalance for the plants, causing them not grow to maturity. Replacement of the soil, and mulching alleviated the problem.
Growing season – Gardens need to be established as early in the season as possible. A shortened growing season limits exposure to ozone.
Insect management – Ongoing organic insect control is imperative to maintaining plant health. Infestation of insects can destroy a garden quickly.
Weather – Access to water for plant health during hot summer days and drought conditions is critical. Also it is important to design the garden with drainage to handle major rain events and even hurricanes!

Overcoming Garden Obstacles

Student Research in the Garden

This garden is meant not only for public interpretation of ozone garden information. This pilot garden also provides a site for NASA interns to continue their atmospheric research, providing yet another connection for visitors to make with real science.

Intern Research



A Progression of Citizen Science Activities

The TEMPO mission is creating a network of museums and public gardens across the country that engages learners in hands-on activities and develops their citizen science skills, enabling them to contribute quantitative and qualitative data on local air quality impact to the overall scientific community.

Key factors in piloting a citizen science progression at the VLM
Worksheets were developed to allow visitors to collect and analyze data that will be compiled and eventually displayed for museum visitors to view.

All activities include NGSS-emphasized scientific practices, and develop key competencies for future contributing members of the citizen science community.

Hands On Learning!

Developing foundational science skills such as, observing, collecting, comparing, classifying, measuring, and making sense of data in the context of air quality

VLM Ozone Activities to Support Citizen Science

Activities were designed to build skills and knowledge that support visitor engagement with citizen science, while being optimized for adult-child interaction in informal or free-choice learning environments. The activities cover basic scientific concepts as well as topics specific to the ozone garden. The activities range from exploring the difference between living and non-living organisms to determining the percentage of ozone injury on a leaf and the resulting impact on plant health.

Kids of All Ages

Ozone Garden Activities

- Living or Non-living?
- What makes a plant healthy?
- Why are the leaves spotted?
- Look at all those spots!
- Sorting Leaves
- Air Quality Index

Activity Engagement
Self-Guided–
Created for visitor participation when the ozone garden is dormant. During the non-growing season, visitors can continue to learn about the garden and ozone.

Volunteer/Staff Facilitated-
Activities that require special tools or extra knowledge about ozone and the garden itself. These activities are best implemented with a volunteer or staff member when the garden is active.

Lessons Learned – Citizen Science for All Ages

Garden plants – Additional plants in transportable containers should be considered for hands-on activities.
Activities – Integrate activities into garden exhibit to enhance science skills and increase understanding about air quality.
Exhibit space – Establish a designated area for self guided ozone garden activities.

Future Steps for the TEMPO Ozone Garden Network

A toolkit based on lessons learned at the VLM will help future museum sites establish successful ozone gardens.
Toolkits will include:

- Guidelines for garden exhibit set-up including garden design, plants, seeds and soil, exhibit signage, and ongoing upkeep
- Documentation of all activities
- Training materials for volunteers and interpreters
- Example summer schedule for visitors to participate in citizen science data collection
- Recommendations of displays for sites to share collected citizen science data with the public
- Incorporate GLOBE protocols into garden activities

Acknowledgments

The TEMPO Student Collaboration and Strategic Communications funding is provided by NASA SMD Earth System Science Pathfinder Earth Venture – Instrument award. The authors would like to thank the TEMPO PI - Kelly Chance, Project Scientist - David Flittner, and Project Manager - Wendy Pennington; the VLM horticulturalists Bruce Peachee and Darl Fletcher; and all the NASA interns: Pablo Sanchez, Abbey Rodjom, Rachel Slank, Zach Fair, Blake Phillips, Emily Gargulinski, Amber Verstynen, Rachel Shaffer, Robert Bujosa, Yanira Favela, Chris Marentette, who worked hard during hot sunny days making the garden a success!