

Aura's Ozone Garden

Despite 44% decrease in OMI NO₂, ozone – induced injury to sensitive plants is still very evident

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NASA
GSFC
Visitor's
Center

Tobacco

Potato

Potato

Bean

An important part of all NASA missions is to communicate the mission science to other scientists, policy & decision makers, and the general public.

Aura STM, Rotterdam, August 2016

Ozone
Monitor
Intake

Back Bed

Coneflower

Milkweed

Bean





Indoor Exhibit

A Simple Message

The ozone layer is beneficial!

Surface ozone is not!

Outdoor Exhibit

A Simple Message

Plants serve as bioindicators of ozone injury that occurs in our own lungs.

Connecting Ozone Garden to Aura NO₂ Data

Ozone: Good up high! Bad Nearby!

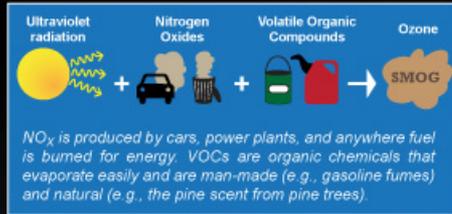
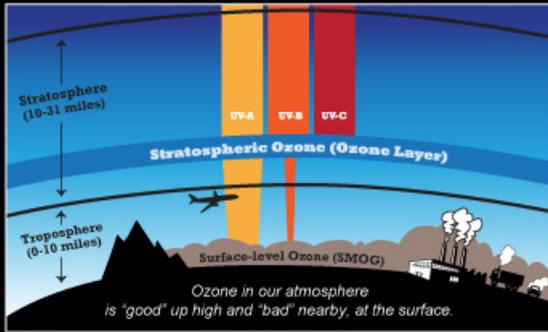
National Aeronautics and Space Administration
Goddard Space Flight Center



NASA's Aura satellite monitors the chemistry of the Earth's atmosphere including ozone and other gases. Ozone is a gas that can be "good" or "bad" depending on where it forms in our atmosphere.

"Good" Ozone

When ozone forms in the upper atmosphere (the stratosphere), it protects life on Earth from harmful ultraviolet (UV) rays from the sun. Overexposure to UV rays can lead to more cases of skin cancer, cataracts, and impaired immune systems. UV exposure can also impact food production by damaging agricultural crops.



"Bad" Ozone

When ozone forms at the surface, where we live and breathe, it is a pollutant. Ground-level ozone is harmful to breathe contributing to a variety of health problems such as worsening asthma symptoms, reducing lung function, even scarring lung tissue after repeated exposure.

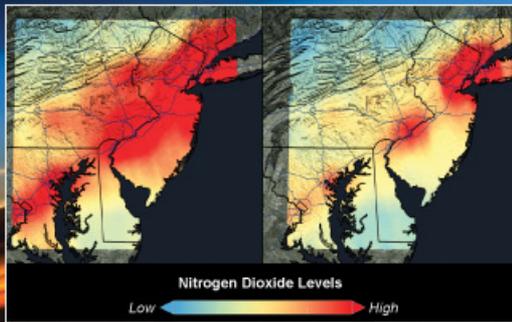
Ozone pollution is the main ingredient in urban smog, but ozone is not emitted directly into the air. Ozone is created by chemical reactions between nitrogen oxides (NO_x) and volatile organic compounds (VOCs) and sunlight.

Observations from NASA's Aura Satellite

While Aura's Ozone Monitoring Instrument (OMI) was not designed to study ground-level ozone, it provides scientists with a global view of a key piece of the equation—nitrogen dioxide (NO₂) a component of nitrogen oxides (NO_x). Nitrogen dioxide has a relatively short lifespan, so it is concentrated near the source of its emission. As a result, when OMI detects the presence of nitrogen dioxide in the atmosphere, scientists can identify and monitor its sources. Concentrations of NO₂ can indicate where high levels of ozone could possibly form.

For more information, visit: <http://airquality.gsfc.nasa.gov>. While air quality is improving, there is still a lot of work to do. The EPA issues forecasts for air quality and can be found at: <http://www.epa.gov/airnow>.

NO₂ measurements from Aura's OMI instrument reveal high concentrations around cities and industrial areas. Aura data of the mid-Atlantic area of the United States show an average of a 20-50% reduction in NO₂ pollution.



Ozone: Bioindicator Garden

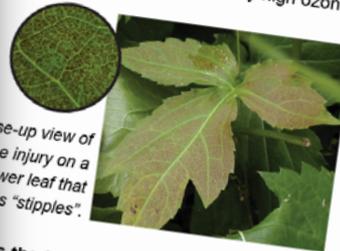
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Ground-level ozone (O₃) is a pollutant. Breathing ozone is unhealthy especially for children, the elderly, and those with asthma. It also can reduce lung function and harm lung tissue. Since we can't see the insides of our lungs, we can use these plants in a bioindicator garden to deduce the likely human health impacts of the high ozone levels. Exposure to high levels of ozone can damage vegetation resulting in reduction of agricultural crop yields, reducing growth of tree seedlings, and damage to foliage affecting the landscape of cities, national parks, and forests.

What is a bioindicator garden?

An ozone bioindicator garden is designed to detect and monitor ozone stress on sensitive and tolerant plants. Certain species serve as excellent bioindicators by expressing typical symptoms, but not all plants show symptoms under even when ozone levels are high. Ozone sensitive plants allow us to readily detect with our eyes the damage caused by high ozone levels.



Close-up view of ozone injury on a leaf showing stippled damage.

Symptoms of ozone injury

- Ozone-induced injury appears as "stipples" that are dot-like areas on the leaf surface.
- More symptoms appear on older leaves found at the base of the plant.
- Ozone-induced injury usually increases with more exposure to ozone air pollution over time.
- With increase injury, the stippled areas appear dark purple, red, or tan to dark brown.

When is the Season for Ozone

Large amounts of ozone occurs when temperatures are warm. Formation of ozone and the presence of ozone injury symptoms begin to occur in late spring or early July. Ozone-induced injury increases with increasing exposure to ozone air pollution throughout the warm summer months.

During the summer, we are asked to reduce driving and use public transit for our cars early in the morning or at the end of the day to reduce the amount of VOCs and NO_x emitted during daylight hours, when sunlight initiates chemical reactions that form ozone.



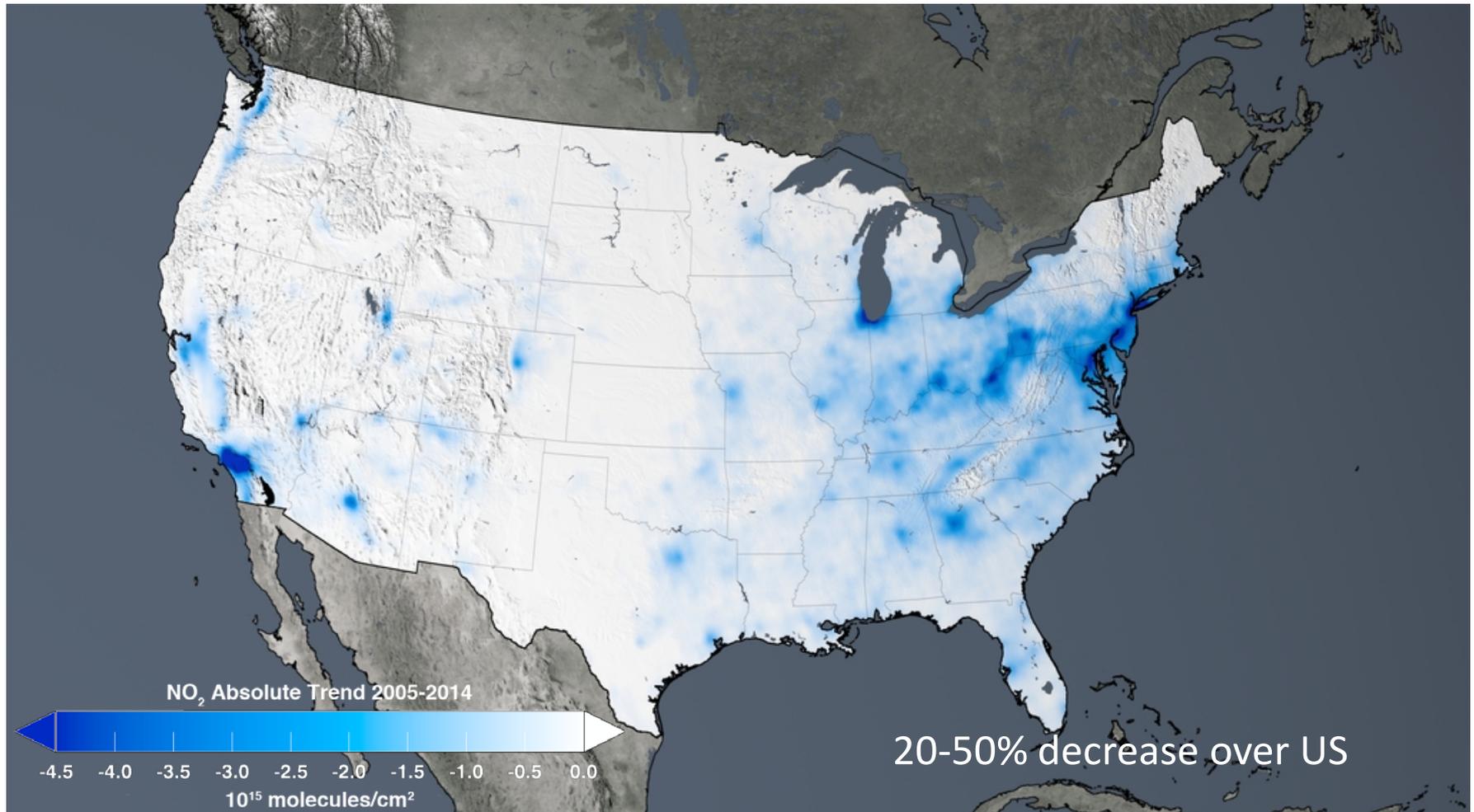
Ozone Garden at NASA's Goddard Space Flight Center.

What is the Evidence of ozone injury where you live?

Signs of ozone injury on flowers, trees, and shrubs are sensitive to ozone. Sensitive flower species include Aster (Common), Dogbane, Milkweed (Common, Tall), and many other species), and Lady in Red (Salvia). Plants that are sensitive to ozone include Beauty berry, Elderberry, and Viburnum. Black cherry, Black locust, Sassafras, Sweetgum, Sycamore, Tree of Heaven, Willows, and Yellow Poplar (Tulip tree) are also sensitive to ozone.

% Difference in OMI NO₂: 2005 - 2014

>90% of Americans who were asked think that USA pollution is bad and getting worse.

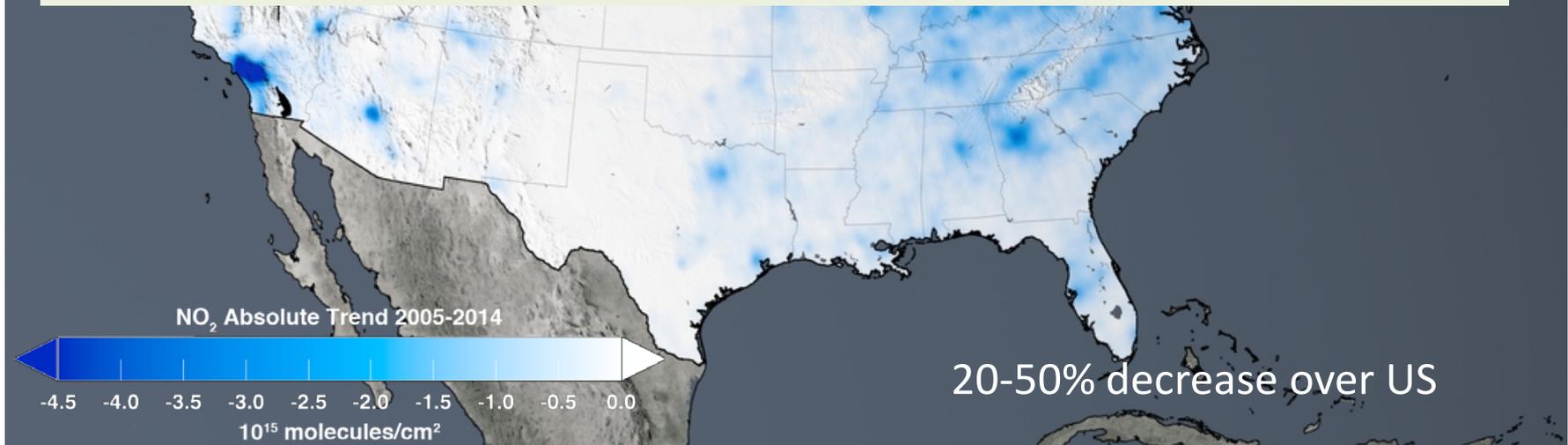


The Clean Air Act is working!

% Difference in OMI NO₂: 2005 - 2014

>90% of Americans who were asked think that USA pollution is bad and getting worse.

Despite large decreases in NO_x, a necessary ingredient for high levels of ozone to form, the Ozone Garden bioindicator plants show that ozone injury is still occurring. *Presumably lung injury too!*

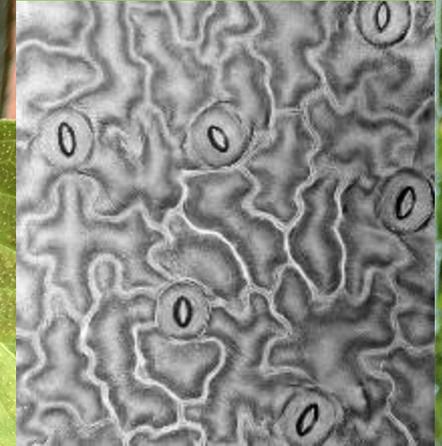


The Clean Air Act is working!

Coneflower

Ozone injury evident >60 ppbv.

Ozone enters a plant's interior via its stomata.



Once inside, ozone chemically reacts with cells, injuring them. Pigment builds-up causing stippling.

Red Stippling on Leaf's Upper Surface
= Symptom of Ozone Injury

Bean

Ozone injury begins at ~40-50 ppbv though many factors affect sensitivity (e.g., soil moisture, relative humidity, etc.)



Tobacco

Ozone injury begins at ~40-50 ppbv.

Severe Ozone Injury



Ozone Tolerant Variety



Moderate Ozone Injury

“Poor Performers”

Can't separate ozone injury from other types of injury.
Ozone injury typically occurs at 60-70 ppbv.

Maryland is hot & humid.
Potatoes like cool & humid.

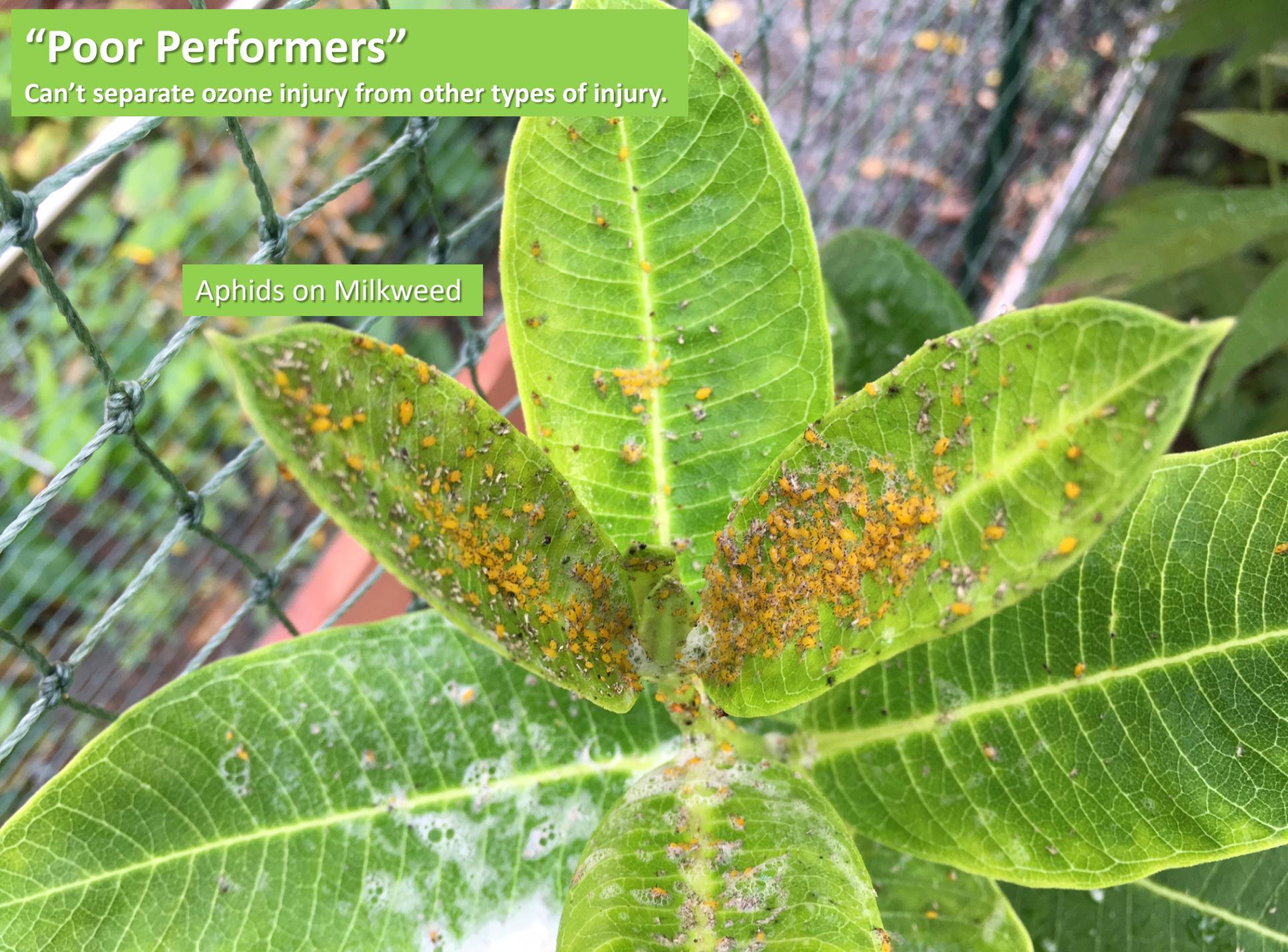
Potato Beetle Devastation



“Poor Performers”

Can't separate ozone injury from other types of injury.

Aphids on Milkweed



Common Milkweed

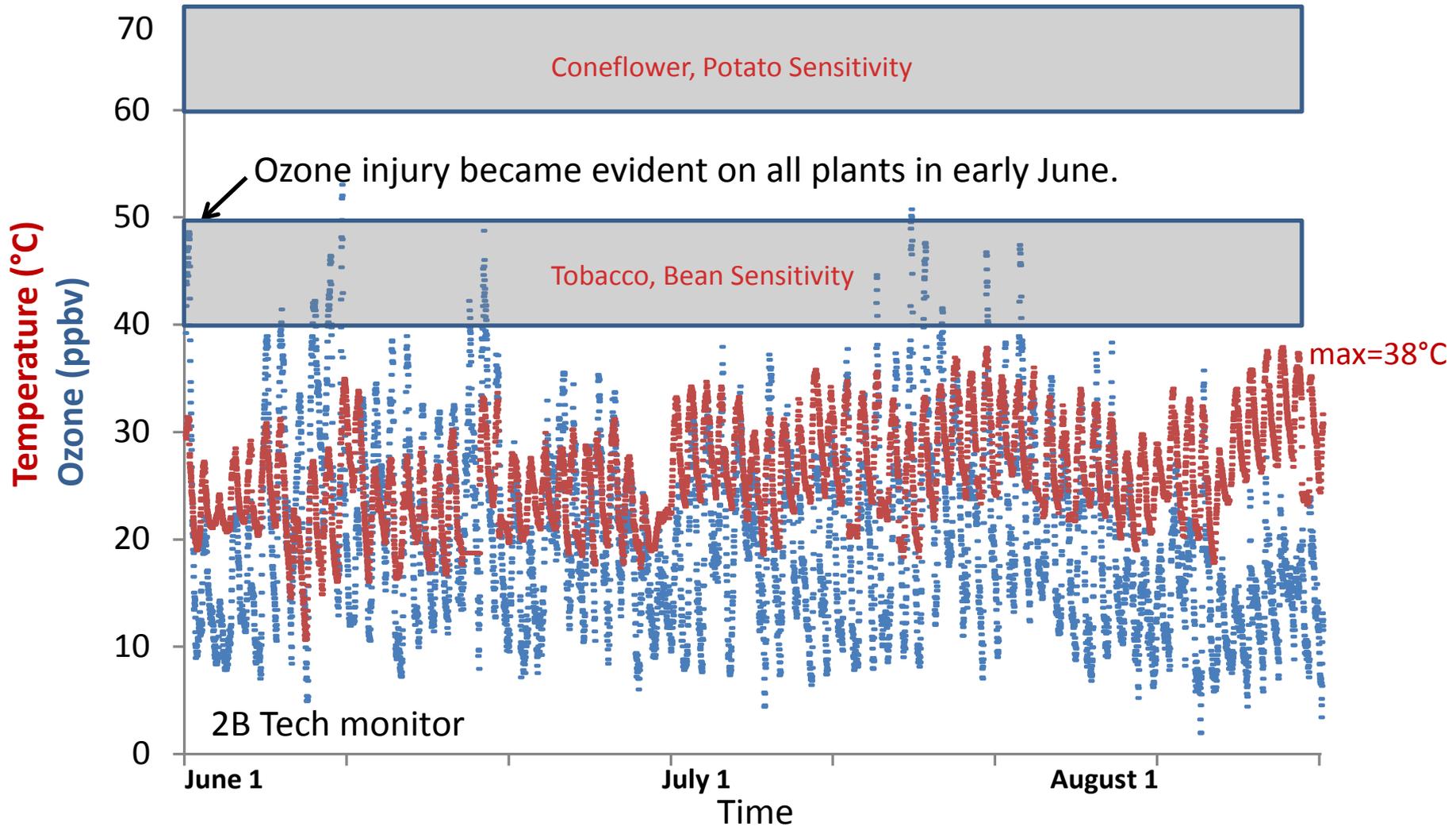
Ozone Sensitive

A symptom of ozone injury is stipple on the upper leaf surface but not on the leaf veins or the lower leaf surface. More stipple can create a "herringbone" fish pattern.



Common milkweed was first published as being an ozone sensitive plant in the mid-1970's following observations of typical ozone symptoms on native plants within the Shenandoah National Park in Virginia. Its sensitivity was proven in lab experiments and outdoor investigations. Common milkweed is now considered as one of the very best natural bioindicators. Milkweed is also essential for the survival of migrating Monarch butterflies.

June 1 – August 17, 2016: *Temperature & Ozone*

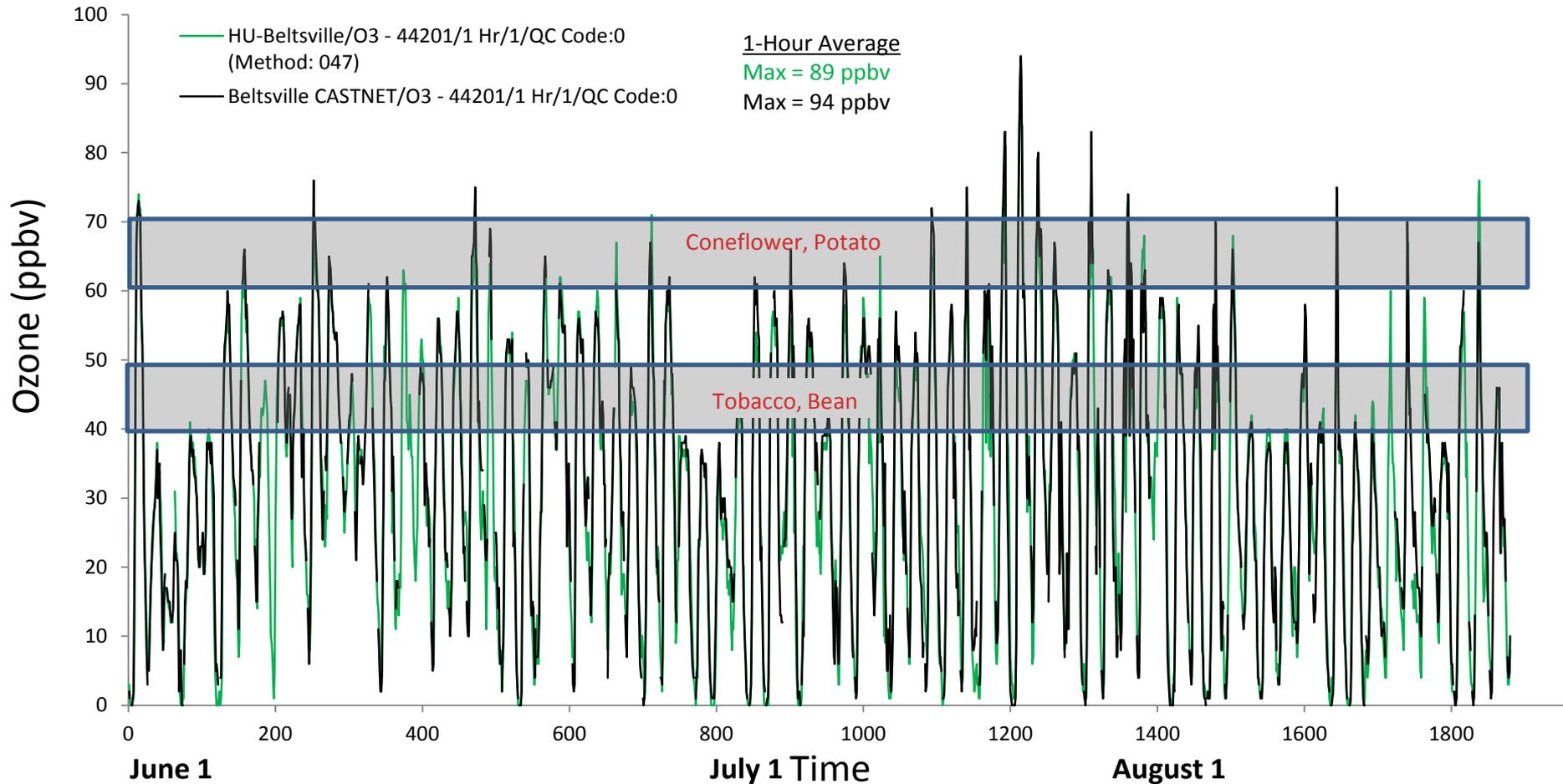


Ozone instrument likely has a big low bias (~20-40 ppbv) as observed ozone injury to plants isn't consistent with such low ozone levels & much lower than nearby ozone monitors.

However, temporal variations seem consistent with other local monitors.

June 1 – August 17, 2016: *Ozone from Nearby Monitors*

Ozone is lower than a decade ago, but certainly still high enough to cause ozone injury!



Local Media & Social Media



Ozone garden and exhibit served as location for local news interviews as part of NASA's Air Quality Media Event Jun. 27, 2014



Aura's deputy project scientist, Dr. Bryan Duncan, consults with plant pathologist Dr. John Skelly as they prepare the ozone garden beds for NASA Goddard's Ozone Garden. This bio-indicator garden is designed to detect and monitor ozone stress on sensitive and tolerant plants. Visitors to the garden can learn about atmospheric chemistry, satellite observations, and public health. aura.gsfc.nasa.gov/outreach/ozonegarden.html



Garden was highlighted during NASA's Earth Day campaign on Facebook in 2016



Outreach specialist Mike Taylor installs the intake hose for the ozone monitor at NASA Goddard's ozone garden in time for the start of the ozone season. The ozone monitoring garden is full of plants that scientists have found to be ozone-sensitive. Plants with ozone damage have very fine colored spots on the upper surfaces of their leaves, and some leaves also turn yellow. aura.gsfc.nasa.gov/outreach/ozonegarden.html

Public Engagement at Visitors Center



During the summer – the ozone garden season, Goddard’s Visitor’s Center sees 3,500 to 4,000 visitors each month.

Visitors at Goddard’s Open House in Sept 2015 learned about air quality, ozone injury and the connection to OMI data.



OZONE GARDEN OBSERVATIONS

Did you know that Colorado's Front Range has high concentrations of ozone pollution?

Unlike the ozone layer found high in the atmosphere, ground-level ("bad") ozone is a toxic air pollutant. High concentrations of ground-level ozone cause human health problems like reducing yields in agricultural crops and the damage to plants. You can even see ozone damage on the leaves of sensitive plants that show visible signs of damage from ozone pollution as it shows up!

How to identify ozone injury on plants

Leaves of plants in this garden will start to show damage if ozone concentrations around the plants are relatively high for extended periods of time. Visible injury on broadleaf plants starts as stippling.

Additional symptoms such as leaf yellowing or necrosis or tissue death can occur as ozone damage accumulates and becomes more severe.

What's the difference between ozone injury and other plant damage?

Be careful in your identification of ozone injury! It is often mistaken for other types of plant damage. To distinguish between them, keep the following points in mind:

- Ozone injury only occurs between the leaf veins.
- Most ozone injury occurs only on the top surface of the leaf.
- Older leaves of sensitive plants will show the most damage.
- Ozone damage starts as stippling. With extended exposure, it can progress to leaf yellowing and patches of tissue death, making the leaves brittle.

Here are examples of stippling damage



Snap bean

Coneflower



WORKSHEET 2

What percent of leaves are damaged on the affected plants?

- 1 What is today's date?
- 2 Choose a plant in the garden that has visible ozone injury.

This will be the plant for which you collect data. What type of plant is it?



Snap bean

Coneflower

Potato

Plant type: _____

- 3 How many total leaves are on the plant?
- 4 How many leaves on the plant show stippling or other visible signs of ozone injury?
- 5 Number of injured plants (question 3):

Total number of plants (question 2): _____

EXAMPLE CALCULATION

Number of injured plants (question 3): _____

Total number of plants (question 2): _____

Note: This example is just a guide, and the numbers you observe will vary. You will see more ozone damage to plants as the season progresses, and the collective data analysis about ozone damage through time.

Next steps – engaging visitors to quantify ozone injury symptoms

WORKSHEET 4

What is the severity of the ozone injury on the affected leaves?

- 1 What is today's date? _____
- 2 Choose a plant in the garden that has visible ozone injury. This will be the plant for which you collect data. What type of plant is it?



Snap bean

Coneflower

Potato

Milkweed

Plant type: _____

- 3 Randomly choose 10 leaves on this plant.
- 4 For each leaf, what is the estimated percent of leaf area that has visible ozone damage?

Use the injury scale and accompanying photos below to categorize the injury to the best of your ability, recording the index value in the table below. The leaf number is only used to identify that there are different leaves, so the order or number does not matter. Be careful to collect data from each leaf only once.

INJURY SCALE

Index Number = Percent Affected

0 = 0 1 = 1 to 30 2 = 30 to 60 3 = 60 to 90 4 = more than 90



Leaf

Injury Index (0-4)

Leaf

Injury Index (0-4)

TOP TEN (ELEVEN) LEARNING EXPECTATIONS FOR OZONE GARDENS

- Ozone air pollution is formed from primary pollutant emissions (nitrogen oxides and hydrocarbons); ozone forms as a secondary pollutant as a result of bright sunlight and high temperatures.
- Long distance transport of this pollutant may occur from large urban areas with emissions from transportation and fossil fuel powered industries.
- Ozone air pollution remains still today as the one air pollutant of greatest concern to plant and human health.
- Regional effects (direct symptoms) continue to be found on both natural vegetation and crop plants in many areas of our country.
- Certain plants, as seen within this garden, are quite sensitive to ozone air pollution and thus they serve as excellent bioindicators such as are planted within this display garden.
- The symptoms of ozone-induced injury are quite distinctive and are shown on the Symptom Description card.
- Ozone symptoms appear on the older leaves found near the bottom of the plants and usually appear later in the growing season due to longer-term exposures
- The typical symptoms for our known- sensitive bioindicator plants are shown on the information cards.
- Varieties of many agricultural crops are selected for tolerance to ozone air pollution...La Chipper potato and S-156 snap bean show such a selection process and would not be grown by farms and large producers.
- Natural vegetation has many ozone sensitive species and these show ozone-induced injury due to season-long exposures to the pollutant even within our more remote Shenandoah National Park.
- There are many other causes of symptoms and injuries that appear on plant leaves...insect feeding, fungi, droughts, nutrient deficiencies, and many other physical damages often occur.

How successful is the NASA Ozone Garden (i.e., visitor engagement metrics)?

Extra Slides

USA pollution went down as population went up!

But >90% of Americans who were asked think that USA pollution is bad and getting worse.

