Great Smoky Mountains National Park
Update on Park Air Resources

Jim Renfro, National Park Service
AAQTF Meeting, Wednesday, April 22, 2015
University of Tennessee - Knoxville, TN

Outline

Policy, Status, Trends, Effects, Projections

• Mandates for Clean Air
• Emissions
• Ozone
• Particulate Matter
• Regional Haze
• Acid Deposition
• Mercury
Good air quality and views are important to the 10 million visitors who come to the Park annually. They expect clean, clear air.
Mandates for Clean Air Protection in National Parks

- **National Park Service Organic Act (1916)**
  - Mission “…Protect park resources… natural, cultural, historic… unimpaired for future generations.”

- **The Clean Air Act (1970) & Amendments (1977, 1990)** afford the greatest protection for Class I Areas:
  - National Parks > 6,000 acres in size.

- **Requires protection of Air Quality Related Values (AQRVs) – Visibility, soils, water, flora, fauna, ecosystems.**
  - Park should be the cleanest area in the U.S.
  - Federal Land Managers (“FLM”) have the affirmative responsibility to protect resources.
  - The FLM has no regulatory authority to control pollution beyond the park boundary. We rely on EPA, State and Local air regulatory programs.
  - Pollutant levels at Great Smoky Mountains historically have been among the highest of any Class I area in U.S.  Good news is air quality is improving.
  - The keys to success have been the long-term continuous monitoring, targeted research, collaborative partnerships leveraging resources, education and public outreach, and policies leading to emission reductions. We are expected to know the condition of our resource through our monitoring programs.
Air Quality and Climate Continuous Monitoring Stations in and near Great Smoky Mountains National Park, TN/NC

- AQ, Winds, Temp, RH, Solar, Precip (NPS, NCDAQ, NEON)
- Min/Max/Observed Temp, Precip (COOP NWS, NPS)
- Winds, Temp, DP, RH, Precip (RAWS NPS, NOAA, NIFC)
- Winds, Temp, RH, Precip (RAMAN, NOAA-ATDD)
- Precip (AFWS, GFD, NCDPS)
- Precip (TVA, USGS)
- Precip/Deposition (NADP, NPS)
- Stream Flow (USGS, GFD, NPS)

Prepared by Jim Renfro, Air Resource Specialist, GRSM 01/30/2015
Goals of the NPS Air Monitoring Program

- **Determine Compliance** with air quality standards;
  - *Do we meet public health and environmental standards?*

- **Establish Baseline** Conditions to identify areas of concern;
  - *How healthy is the park and how does it compare to other locations?*

- **Determine Trends** with Long-term continuous data;
  - *Is the problem getting better or worse?*

- **Link to Biological Effects**;
  - *How much pollution is too much (e.g. “cause and effect research”)?

- **Utilize Modeling** as a tool to demonstrate compliance;
  - *How effective are emission control strategies (e.g. attainment, progress)?*

- **Review New Sources** of pollution:
  - *What are the sources & impacts of new & existing sources (e.g. NSR/PSD program)?*

- **Share data** to promote understanding with the public, scientific community, Congress, EPA, States and local communities.
Look Rock Air Quality Monitoring Station

- Winds Anemometer
- Ozone & Dry Deposition Inlets
- Temp, RH Probes
- Trace Gas Inlet (SO2, CO, NO-NOy, NO2)
- Nephelometer
- Solar sensor
- Ammonia filter
- Rain gauge
- PM2.5 Inlet
- Visibility Particle Samplers
Emissions Inventory of Sulfur Dioxide and Nitrogen Oxide in the Southeast U.S.

**SO2 Emissions**
(AL, FL, GA, KY, MS, NC, SC, TN, VA, WV)

- **Utilities**: 76%
- **Industry**: 20%

**NOx Emissions**

- **Power Plants**: 40%
- **Highway Vehicles**: 16%
- **Off-Road Vehicles**: 28%
- **Area**: 15%

Source: VISTAS 2006
75% Reduction
71% Reduction
Annual SO2 and NOx Emissions for the 4 Eastern TVA Power Plants (in Thousands of Tons)

SO2

Total of 370,000 Tons Reduced in the past 15 years

Down 95%

NOx
2011 Tennessee NOx and VOC Emissions by Source Sector

- **Mobile**: VOC = 118,969, NOx = 243,130
- **Fuel Combustion**: VOC = 6,979, NOx = 63,755
- **Solvents**: VOC = 134, NOx = 96,218
- **Industrial Processes**: VOC = 29,077, NOx = 11,271
- **Fires (Prescribed & Wild)**: VOC = 30,267, NOx = 2,828
- **Natural/Biogenics**: VOC = 787,039, NOx = 16,506

Source: 2011 NEI

Park NOx = 123 TPY
Park VOC = 71 TPY
Park Efforts to Reduce Emissions

• **Cleaner Vehicles and Fuels**
  – Use of biodiesel
    • Fleet (B20) and Park HQ heating (B50)
  – Hybrid electric vehicles
  – Electric utility vehicles in campgrounds
  – No idling buses at visitor centers
  – Cades Cove free of motorized vehicles (M, W)

• **Shuttle Transit Systems**
  – Gatlinburg trolleys to campground (Elkmont), Hiking Trail (Laurel Falls), and Sugarlands VC
  – Cherokee shuttle service between gateway communities

• **Cleaner Electricity**
  – Solar power air quality station and radio system
  – Hot water heater at Sugarlands Visitor Center
  – Green Power Switch (SCES, TVA)

• **LEED Gold Buildings**
  – Twin Creeks Science Center,
  – Oconaluftee Visitor Center

• **Air Quality Action Days**
  – Restrict mowing/weedeating
Natural Factors that Predispose Resources

“Natural Ingredients”

- High pressure and frequent air stagnation events;
- Sunlight and heat that increases chemical reactivity;
- Elevation and topography, higher winds, more clouds;
- Rainfall and humidity which affect deposition & haze;
- Organic emissions from trees (isoprene) affects O3 & PM formation;
- Low buffering capacity in streams & acid soils;
- Old-growth, slow growing forests (less N demand)
Ozone Pollution

- Powerful respiratory irritant
- Damages forests (and crops)
- NOx + VOC + Sunlight + Heat = O3
- Weather, terrain, elevation influences
Ozone Non-Attainment Areas
(Effective April 15, 2004)

CATEGORY/CLASSIFICATION

Severe 17 Los Angeles
Serious - Riverside Co (Coachella Valley), San Joaquin, Sacramento, CA
Moderate
Moderate EAC Greensboro, NC
Marginal
Subpart 1 (Basic)
Subpart 1 EAC (Basic)
EPA Ozone Nonattainment Areas
(2008 76 ppb Standard)

Nonattainment areas are indicated by color. When only a portion of a county is shown in color, it indicates that only that part of the county is within a nonattainment area boundary.
What does Nonattainment mean?

- Area that **exceeds or contributes** to an area that exceeds the public health standard.
- **Stigma** of a “bad air” area
- Economic growth concerns
  - Permitting polluting industry more difficult; may require emission offsets.
  - Federal highway funds can be frozen; Conformity test for all new roads.
- State Implementation Plans & Contingency Measures due to EPA.
- TDEC & EPA working on re-attainment designation.
- EPA has proposed tightening the 2008 Standard from 75 ppb to 65-70 ppb.
  - Proposed new rule (Dec. 2014); Final rule (Oct. 1, 2015)
- Need for a Secondary Ozone Standard to protect Vegetation
  - Park effects data is part of EPA’s Integrated Science & Risk Assessment
  - EPA considering a requisite primary standard equal to seasonal exposures
Trend in Ozone Design Values for GRSM & Knoxville Area Monitors
(3-year average of the 4th highest 8-hour average)

1997 Standard
2008 Standard

Knox Co, TN
Blount Co, TN - Look Rock
Sevier Co, TN - Cove Mtn
Jefferson Co, TN
Loudon Co, TN
Anderson Co, TN
Haywood Co, NC - Purchase Knob

Ozone, ppb


Down 36%

Proposed Dec. 2014
Final Rule Oct 2015
Typical Daily Ozone Pattern at Knoxville and GRSM Ridgetop Monitors - April 14, 2010

The Park has measured >300 Exceedances of the Ozone Standard since 1997.

Ozone, ppb

Hour of the Day

Local ozone formation and transport from aloft and afar.
Frequency of Look Rock Ozone Hourly Values > 75 ppb by Wind Direction and Time of Day
Counties Where Measured Ozone is Above Proposed Range of Standards (65 – 70 parts per billion)

- 358 counties would violate 70 parts per billion (ppb)
- 200 additional counties would violate 65 ppb for a total of 558

Based on 2011 – 2013 monitoring data
Ozone Effects to Forests

- Park has a long history of ozone effects to vegetation research (since 1982).

- Ozone below the primary standard damages 30 species of plants by interfering with photosynthesis causing:
  - visible leaf injury
  - growth reductions
  - species composition changes
  - water quantity changes in soils & streams

Ozone-Injured Black Cherry

Ozone-Injured Tall Milkweed and Cut-leaf Coneflower
Recent Results – Water flux alterations

Research papers published in the journal New Phytologist

Key summary of findings:

1. Ozone was associated with a slowdown in mature forest tree growth patterns (water loss, sap flow) contributing to episodic and net seasonal losses in stem growth of 30-50% for most species studied in a high ozone year.
2. Increased whole-tree canopy stomatal conductance, depletion of soil moisture in the rooting zone, increased night-time respiration, and reduced late-season streamflow in forested watersheds were detected in response to increasing ambient ozone levels.

Implications for Climate Change

Increased water use by trees should be expected in a warming climate.

Ozone will likely amplify adverse effects of climate warming on forest growth, stream health, water supply (from vapor to streams).
W126

- W126 is a sigmoidally weighted function ("S" curve) assigning higher weights to higher ozone levels. It’s a cumulative exposure index, not an average.

- Step 1 – compute weighted concentration for each hour from 8am through 7 pm (Mar-Oct);
- Step 2 - Add hourly values for the daily sum;
- Step 3 - Add daily values for the monthly sum;
- Step 4 – Select highest 3 consecutive-month sum;
- Step 5 – Compute the 3-year average of the maximum 3-month sum from each 3-year period.
Trends in W126 Ozone Exposures at GRSM

3-yr avg. of the 3-mo. maximum daylight (8am-8pm)

- Look Rock, Blount Co, TN
- Cove Mountain, Sevier Co, TN
- Clingmans Dome, Sevier Co, TN
- Purchase Knob, Haywood Co, NC
- Cades Cove, Blount Co, TN

EPA Proposed Secondary Ozone NAAQS 13-17 ppm-hrs range; also considering 7-13 ppm-hrs
National Surface W126 Ozone Exposures
2006-2010

Source: EPA Welfare Risk and Exposure Assessment for the Ozone NAAQS
Tulip Poplar (Liriodendron tulipifera) (Recent Conditions)

Source: EPA Welfare Risk and Exposure Assessment for the Ozone NAAQS
Source: EPA Welfare Risk and Exposure Assessment for the Ozone NAAQS
Quaking Aspen (Populus tremuloides) (Recent Conditions)

Source: EPA Welfare Risk and Exposure Assessment for the Ozone NAAQS
Source: EPA Welfare Risk and Exposure Assessment for the Ozone NAAQS
Regression Analysis for the W126 Ozone Index and 8-Hour Ozone Design Value using Ozone Monitoring Data from GRSM

3-yr Avg of 3-mo max daylight (8am-8pm) W126 and 3-yr avg of 4th highest 8-Hour avg (1989-2013)

\[ y = 0.0005x^3 - 0.0546x^2 + 2.6292x + 51.258 \]

\[ R^2 = 0.9215 \]

\[ N = 100 \]

8-Hour Design Values

- 75 ppb Primary O3 NAAQS
- CASAC: 7-15 ppm-hours
- Foliar injury: 5-9 ppm-hours

* W126 exposure to cause >10% growth reduction for plant species of known sensitivity at GRSM
Ponderosa Pine
Quaking Aspen
Particulate Matter (PM2.5)

- PM2.5 is made up of particles (<2.5 microns in diameter): sulfate, organics, ammonium, nitrate, elemental carbon, soil, dust, sea salt
- EPA has 2 PM2.5 public health standards

**Annual PM2.5 Standard**

15 µg/m³ (1997)

**Daily PM2.5 Standard**

35 µg/m³ (was 65 µg/m³ 1997-2006)
Areas Violating the 2012 Annual PM2.5 Public Health Standard (Non-attainment Areas)

66 counties don't currently meet 12 ug/m³

EPA will not decide who needs to improve air quality to meet the standard until 2014 at the earliest. States will have until 2020-2025 to meet the standard.

Source: 2009-2011 air quality data as of July 15, 2012
For more information: www.epa.gov/pm
Annual PM$_{2.5}$ Design Values in the GRSM Region
3-Year Rolling Annual Average PM$_{2.5}$ Concentrations

1997 Health Standard
Down 49% 2012 Std

PM$_{2.5}$, µg/m$^3$

Knox Co, TN
Loudon Co, TN
Roane Co, TN
Blount Co, TN
Haywood Co, TN
Swain Co, NC
Buncombe Co, NC
Look Rock, TN
Visibility
Concerns with Regional Haze

“Shaconage”
Cherokee word for...”land of blue mist-like smoke”,

“Viewing Scenery” is the #1 reason ~10 million visitors come to the Park annually which generate nearly $2 billion in local revenues.
EPA Regional Haze Rule (1999)

- Monitor Baseline Visibility at all 156 Class I Areas
  - 5-Yr Baseline 2000-2004
  - At Look Rock since 1980

- Goals of the Haze Rule
  - Restore the 20% haziest days
  - Protect 20% best/clearest days
  - Be at natural conditions by 2064

- State Implementation Plans (SIPs)
  Reasonable Progress & Retrofit Emission Controls
  - TN & NC have EPA-approved Haze SIPs (2008)
    - NPS reviewed Interim Progress SIPs (TN & NC 2013)
Particle Contributions to 20% Haziest Days

- Ammonium Sulfate: 84%
- Organic Carbon: 10%
- Elemental Carbon: 3%
- Soil, Course, & Sea Salt: 1%
- Ammonium Nitrate: 2%

Source: IMPROVE 2004-2008
Light Extinction on the 20% Haziest Days by Year
Great Smoky Mountains National Park – Look Rock (Source IMPROVE)

*Light extinction: the loss in light intensity due to scattering and absorption measured in inverse megameters (Mm⁻¹).
Monitor ID: GRSM1, TN
Then...
1998
9 mile Visual Range
33 deciviews

Now...
2013
32 mile Visual Range
20 deciviews
Glide Path to Natural Visibility Conditions

Great Smoky Mountains National Park - 20% Worst & Best Days

- 20% Worst Observations
- Glide Path to Natural Conditions
- 2018 VISTAS Modeled Prediction
- 20% Best Observations

Haziness Index (Deciviews)

Visual Range (Miles)

- 1990 to 2022 data points
- 2018 VISTAS Modeled Prediction

Baseline worst: 30.28
Baseline best: 13.58

Data points for years:
- 1992: 29.01
- 1994: 25.50
- 1996: 22.69
- 1998: 19.53
- 2000: 16.37
- 2002: 13.20
- 2004: 11.31
- 2008: 12.15
- 2010: 13.58
- 2018: 23.66
- 2020: 13.20
- 2022: 11.31

Great Smoky Mountains National Park - 20% Worst & Best Days

Haziness Index (Deciviews)

Visual Range (Miles)

Data points for years:
- 1990: 12.15
- 1992: 13.58
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Baseline worst: 30.28
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2018 VISTAS Modeled Prediction
Where is the Sulfate Haze Coming From that is Measured at the Park?

65% of the sulfate comes from the Southeast U.S.

Source: VISTAS
Acid Deposition

Effects to soil quality, water quality, aquatic organisms, forest health

Wet Deposition

Dry Deposition

Cloud Deposition
Annual Sulfate & Nitrate Wet Deposition in Monitored National Parks (Source: NADP, 2004-2013)

<table>
<thead>
<tr>
<th>Deposition, kg/ha/yr</th>
<th>Western U.S.</th>
<th>Eastern U.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulfate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrate</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

21.3
Trends in Sulfate, Nitrate and Ammonium Deposition at GRSM- Elkmont Source: (NADP-TN11)

Wet Deposition Monitoring
- 264 U.S. sampling sites (37 NPs)

- Sulfate-S: -62%
- Nitrate-N: -29%
- Ammonium-N: 0%
Annual Average pH and Precipitation-Weighted Mean Sulfate and Nitrate Concentrations at GRSM-Elkmont

(Source: NADP-TN11)

- **Sulfate**
- **Nitrate**
- **pH**
Sulfate ion wet deposition

2012

National Atmospheric Deposition Program/National Trends Network
http://nadp.isws.illinois.edu
Dry Deposition Sampling (CASTNet)

- 83 U.S. CASTNet monitoring sites (25 NPs)

Three air filters collect the pollutants over 1-week

Gas and particle concentrations in air are measured by filter packs and then used to estimate daily dry deposition

<table>
<thead>
<tr>
<th>Whatman</th>
<th>Gaseous</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SO₂</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nylon</th>
<th>Gaseous</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HNO₃, SO₂</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Teflon</th>
<th>Particulate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SO₄²⁻, NO₃⁻, NH₄⁺, Ca, Na, Mg, Cl</td>
</tr>
</tbody>
</table>

Filter packs are open-faced, with no size exclusion

- 20% of S and N deposition can be from coarse particles
- HNO₃ reacts with inlets
Annual Dry Deposition of Nitrogen and Sulfur
GRSM - Look Rock (Source: CASTNet)

Kg/Ha

-65%
No change
-73%
-73%
-88%

Down 77%
Trend in “Total” Sulfate Deposition
(via “Throughfall collector”)

- Noland Divide Throughfall
- Elkmont Wet-only

Down 72%
Annual Ammonia (NH3) Emissions and Ammonium (NH4) Deposition

- Ammonia emissions up 5% 2002-2012
- Emitted primarily from agriculture (volatilization of manure/urine from cattle, swine, poultry operations and fertilizer app).
- Contributes to N deposition, acidification of soils/streams, particle formation, and haze.
- Not directly regulated, expected to increase.
- Park is part of the National Ammonia Monitoring Network (NADP-AMoN)

Source: NADP
Ammonia (NH$_3$) Concentrations at Look Rock
Ammonia Monitoring Network (AMoN) - Look Rock TN01 (Bi-weekly avg, 2011-2014)

Radiello Diffusion-Type Passive Sampler
Phosphoric acid impregnated cartridge, then removed with DI H2O

Up 33%
20-Year Change in the Average $\text{NH}_4^+$ fraction of Wet Inorganic Nitrogen Deposition at NADP Sites

1990-1992

2010-2012

NH$_x$ %

Wet Deposition, kg/ha/yr

Ammonium Fraction

NH4-N, NO3-N, NH4 Fraction


0.1 0.2 0.3 0.4 0.5 0.6

0 1 1.5 2 2.5 3

57
Too Much Nitrogen Leads to Nitrogen Saturation Effects

“Overloaded with too much of a good thing”

**Terrestrial Effects:**
- Alters soil chemistry and fertility;
- Depletes soil nutrients (soil calcium loss into streams);
- Soil aluminum toxicity in soils (Al:BC/Ca ratios);
- Forest health concerns (growth and composition).

**Aquatic Effects:**
- Excess nitrate “leaks” into streams;
- Lowers stream acid “buffering” capacity (ANC) and pH;
- Leads to chronic and episodic acidification;
- Release of toxic aluminum into surface waters;
- Loss of aquatic diversity & trout range and survival;
- Violation of Clean Water Act, 303(d) impairment, TMDL
Total $\text{SO}_4^{2-}$, $\text{NO}_3^-$ and $\text{NH}_4^+$ deposition in 2011 at GRSM (calculated by Weathers et al 2006)
GRSM Water Resources

- 2,116 miles of streams, 1\textsuperscript{st}-6\textsuperscript{th} order, 5 Outstanding National Resource Waters ONRWs, and 100’s of wetlands and springs
## Stream ANC Toxicity Thresholds for Brook Trout

<table>
<thead>
<tr>
<th>Brook Trout Category</th>
<th>ANC Class</th>
<th>ANC Range (ueq/L)</th>
<th>Brook Trout Response</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Suitable</strong></td>
<td>Adequate buffering</td>
<td>&gt; 50</td>
<td>Reproducing brook trout populations expected where the habitat is suitable</td>
</tr>
<tr>
<td><strong>Indeterminate</strong></td>
<td>Potentially sensitive</td>
<td>20-50</td>
<td>Extremely sensitive to acidification; brook trout response variable</td>
</tr>
<tr>
<td><strong>Marginal</strong></td>
<td>Episodically acidic</td>
<td>0-20</td>
<td>Sub-lethal and/or lethal effects on brook trout possible</td>
</tr>
<tr>
<td><strong>Unsuitable</strong></td>
<td>Chronically acidic</td>
<td>&lt; 0</td>
<td>Lethal effects on brook trout probable</td>
</tr>
</tbody>
</table>

ANC = acid neutralizing capacity
Mean Acid Neutralizing Capacity (ANC) for Measured Streams in GRSM (1991-2013)
Average Stream pH
ANC Classes and Critical Load Modeling Sites (PNeT-BGC)
Great Smoky Mountains National Park, TN/NC
42 miles of lost Brook Trout from acid deposition
In 2006, TDEC listed 12 Park streams in TN (67km) on EPA’s 303d list due to low stream pH (<6.0) from acid deposition.

In 2010, Total maximum daily loads (TMDLs) for pH/ANC were established by TDEC. (TMDL is the total amount of a pollutant that can be assimilated by a receiving water body while achieving water quality standards). Clean Water Act is weak to address non-point sources of pollution causing the violation.

Critical loads for acid deposition for park streams are being developed by Syracuse Univ, EPA, and NPS. Critical load is the level of deposition above which resource impairment or harmful effects occur.

Next Steps: Complete critical load modeling with Syracuse Univ. and EPA and share information with key stakeholders (EPA, States, policy-makers, enviro. groups.)
Conceptual Example of Critical Load and Target Loads for Acid Deposition to Protect Stream pH at Great Smoky Mountains NP

**Critical Load:** Level of deposition above which resource impairment or harmful effects occur.

**Target Load(s):** Policy-based acceptable intermittent level of deposition along path to final deposition goal.

- Used to evaluate ecosystem conditions
- Set management goals
- Guide & evaluate air mgt. strategies

![Graph showing N+S Deposition over time with critical load and target loads marked.](image-url)
Stream Monitoring Flume in Noland Divide Watershed
Storm Events and Episodic Acidification:
Acid Neutralizing Capacity (ANC) at Noland Divide Watershed

Streamflow, ft³/sec
ANC, mEq/l

Julian Day

304 305 306 307

NE Flow
NE ANC
Acid-Sensitive Ecoregions from Scheffe et al. 2014
EPA’s Atmospheric Acidification Index (AAI)
A New Regulatory Metric Linking Atmospheric and Biogeochemical Models to Assess Potential Aquatic Ecosystem Recovery

A Potential Approach for the NOx/SOx Secondary National Ambient Air Quality Standard to protect Water Quality/Stream Chemistry (Acid Neutralizing Capacity)

*Considered by EPA in 2010, but dropped, not promulgated, needed further study.*

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**GAO Report to Congressional Requesters**

**WATER QUALITY**

EPA Faces Challenges in Addressing Damage Caused by Airborne Pollutants

GAO recommended “that the EPA Administrator determine whether EPA can obtain in a timely manner the data it needs to establish a secondary NAAQS adequate to protect against the effects of acid rain ...”
Mercury Deposition and Bioaccumulation

- GRSM monitors high deposition of mercury (inorganic non-harmful), especially at higher elevations.
- Most mercury deposited at park comes from coal-fired power plants air emissions.

- Bioaccumulation of the harmful form (organic methyl-mercury) in the food web is of concern.
- Methylating trophic pathways exist in park showing up in terrestrial organisms (e.g. birds, salamanders, insects, spiders)
- Further study needed to determine pathways & risk.
Annual Total Wet Mercury Deposition
(Source: Mercury Deposition Network)

Deposition, ng/m²

Natural Levels

Overall Improving Air Quality Trends

- Nearby TVA Emissions.. down 95%
  - Eastern U.S. emissions down 76%
- Ozone pollution.............down 36%
  - Growing-season exposures down 64%
- Particle pollution..........down 49%
- Haziness (worst days)..down 130%
- Haziness (best days).....down 69%
- Sulfate wet deposition...down 57%
- Nitrate wet deposition...down 23%
- S & N dry deposition.......down 77%
- S throughfall deposition...down 72%
- Ammonium wet deposition.... no change
- Mercury deposition no change (but increasing since 2007)
Thank You

Email: jim_renfro@nps.gov  Phone: (865)436-1708

National Park Service
U.S. Department of the Interior