National Park Service

EXPERIENCE
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Ozone in the National Parks of Western Washington

Elizabeth Waddell
Air Resources Specialist
Pacific West Region
206 220 4287
Elizabeth_waddell@nps.gov

Overview

- Legislative mandate – role of FLM
- Conceptual model of air pollution
- Ozone exposure overview
- Ecosystem effects at current levels
- Ozone trends – FLM perspective
- Challenges of monitoring in National Parks

Legislative Mandate

to "**conserve the scenery and the natural and historic objects and wild life therein** and to provide for the enjoyment of the same in such manner and by such means as will **leave them unimpaired** for the enjoyment of future generations." *(NPS Organic Act); Forest Service Organic Administration Act of 1897* protects watersheds

"Wilderness areas…shall be administered…in such a manner as will **leave them unimpaired** *for future use and enjoyment as wilderness…" (Wilderness Act of 1964)*

*"…***preserve, protect and enhance the air quality** *in national parks, national wilderness areas, national monuments, national seashores…" (Clean Air Act as amended in 1977)*

"…the Federal Land Manager should assume an aggressive role in protecting the air quality related values of land areas under their jurisdiction. **In cases of doubt the land manager should err on the side of protecting the air quality-related values for future generations**." *(Senate Report No. 95-127, 95th Congress, 1977)*

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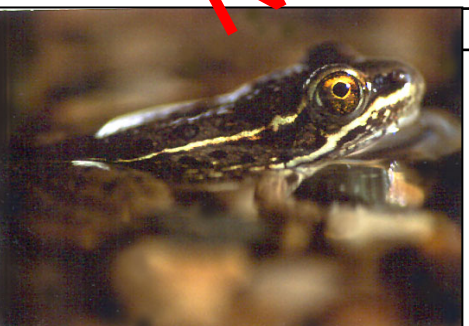
NO REGULATORY AUTHORITY

*"…***preserve, protect and enhance the air quality** *in national parks, national wilderness areas, national monuments, national seashores…" (Clean Air Act as amended in 1977)*



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Legislative Mandate

Ecosystem change due to emissions from this is OK

Ecosystem change due to emissions from this is not OK

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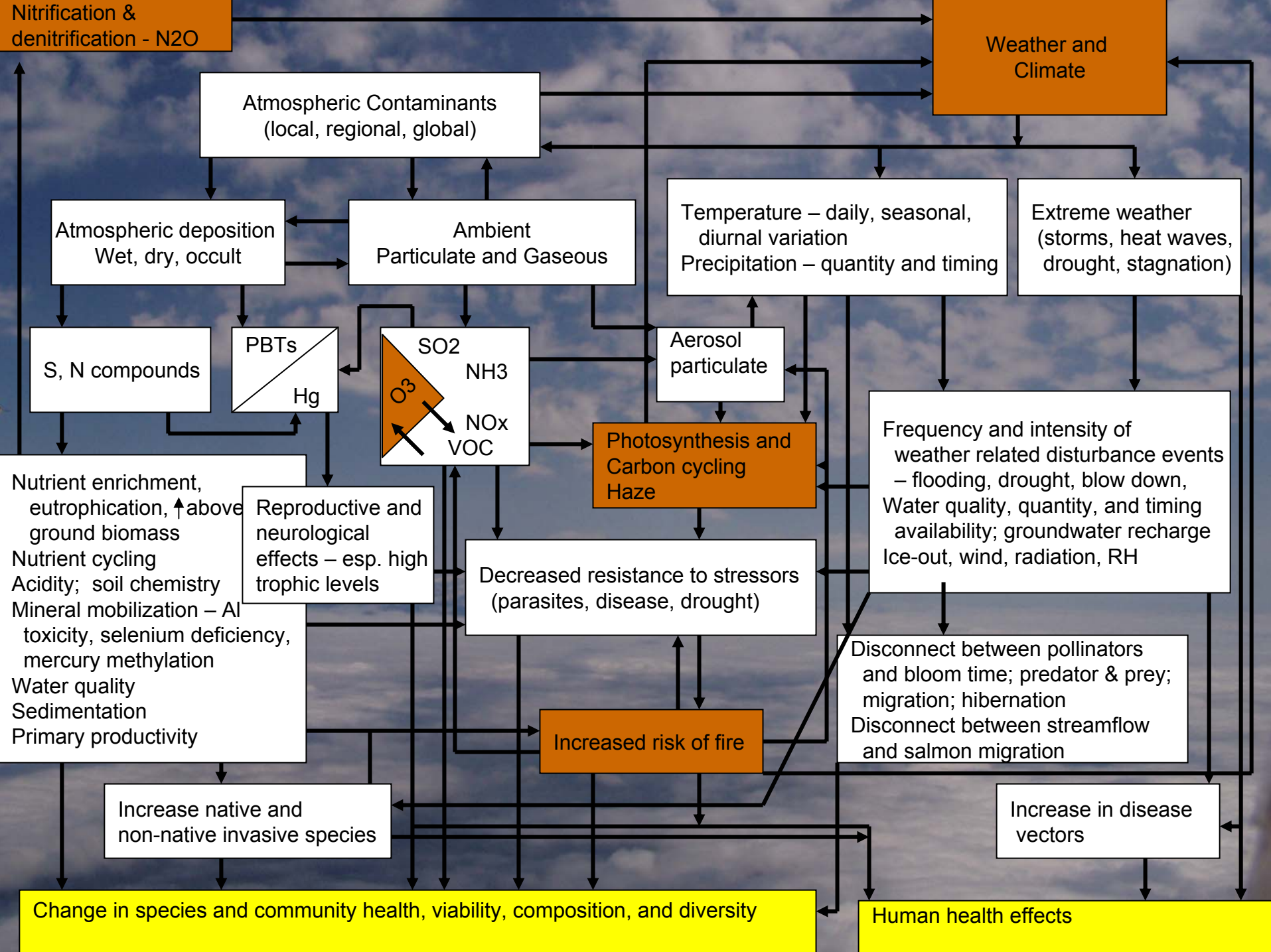
Nitrification & denitrification - N2O
Weather and Climate
Atmospheric Contaminants (local, regional, global)
Atmospheric deposition Wet, dry, occult
Ambient Particulate and Gaseous
Temperature – daily, seasonal, diurnal variation
Precipitation – quantity and timing
Extreme weather (storms, heat waves, drought, stagnation)
S, N compounds
PBTs
Hg
SO2
NH3
O3
NOx
VOC
Aerosol particulate
Photosynthesis and Carbon cycling
Haze
Frequency and intensity of weather related disturbance events – flooding, drought, blow down,
Water quality, quantity, and timing availability; groundwater recharge
Ice-out, wind, radiation, RH
Nutrient enrichment, eutrophication, ↑above ground biomass
Nutrient cycling
Acidity; soil chemistry
Mineral mobilization – Al toxicity, selenium deficiency, mercury methylation
Water quality
Sedimentation
Primary productivity
Reproductive and neurological effects – esp. high trophic levels
Decreased resistance to stressors (parasites, disease, drought)
Disconnect between pollinators and bloom time; predator & prey; migration; hibernation
Disconnect between streamflow and salmon migration
Increased risk of fire
Increase native and non-native invasive species
Increase in disease vectors
Change in species and community health, viability, composition, and diversity
Human health effects

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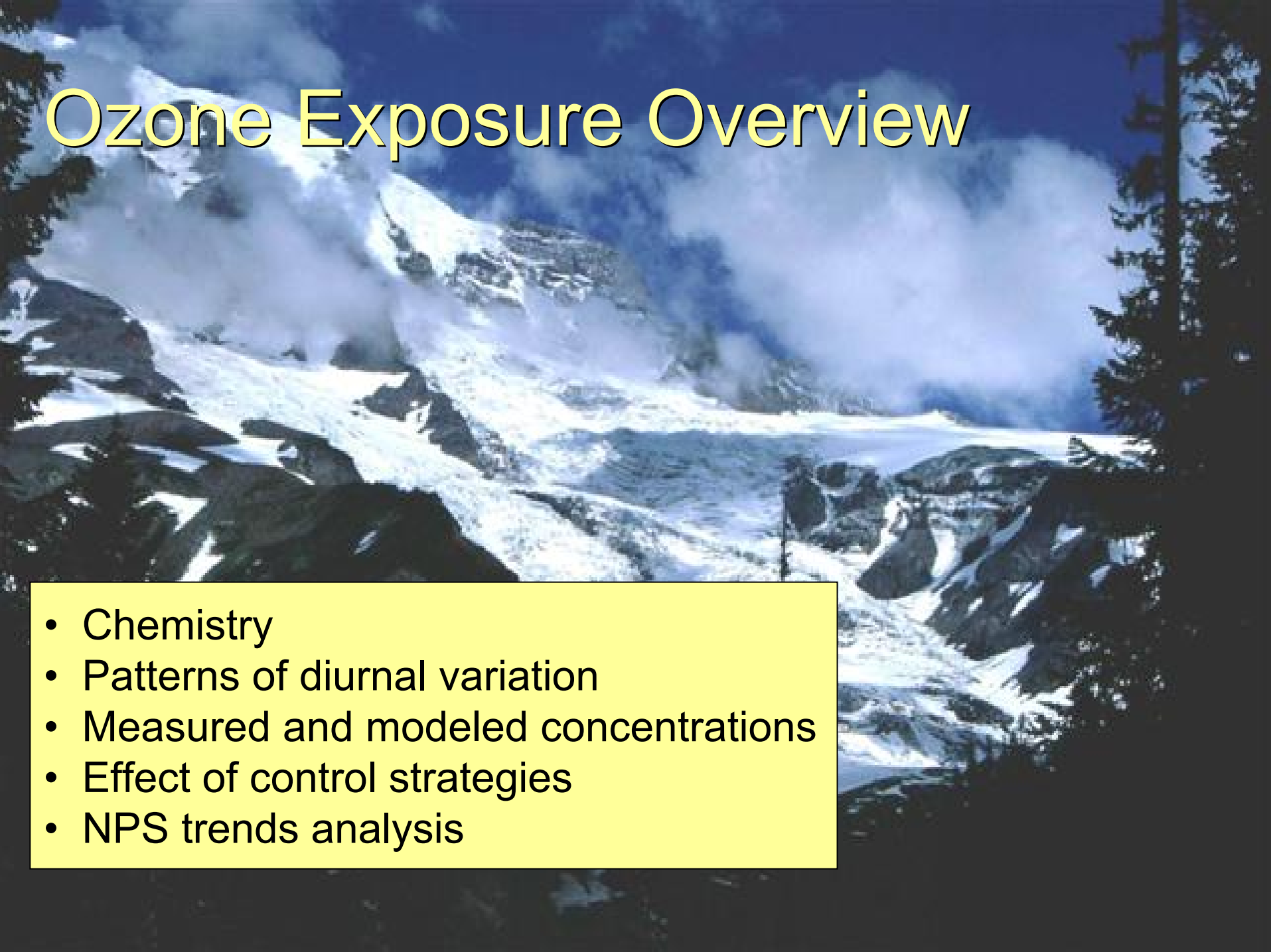
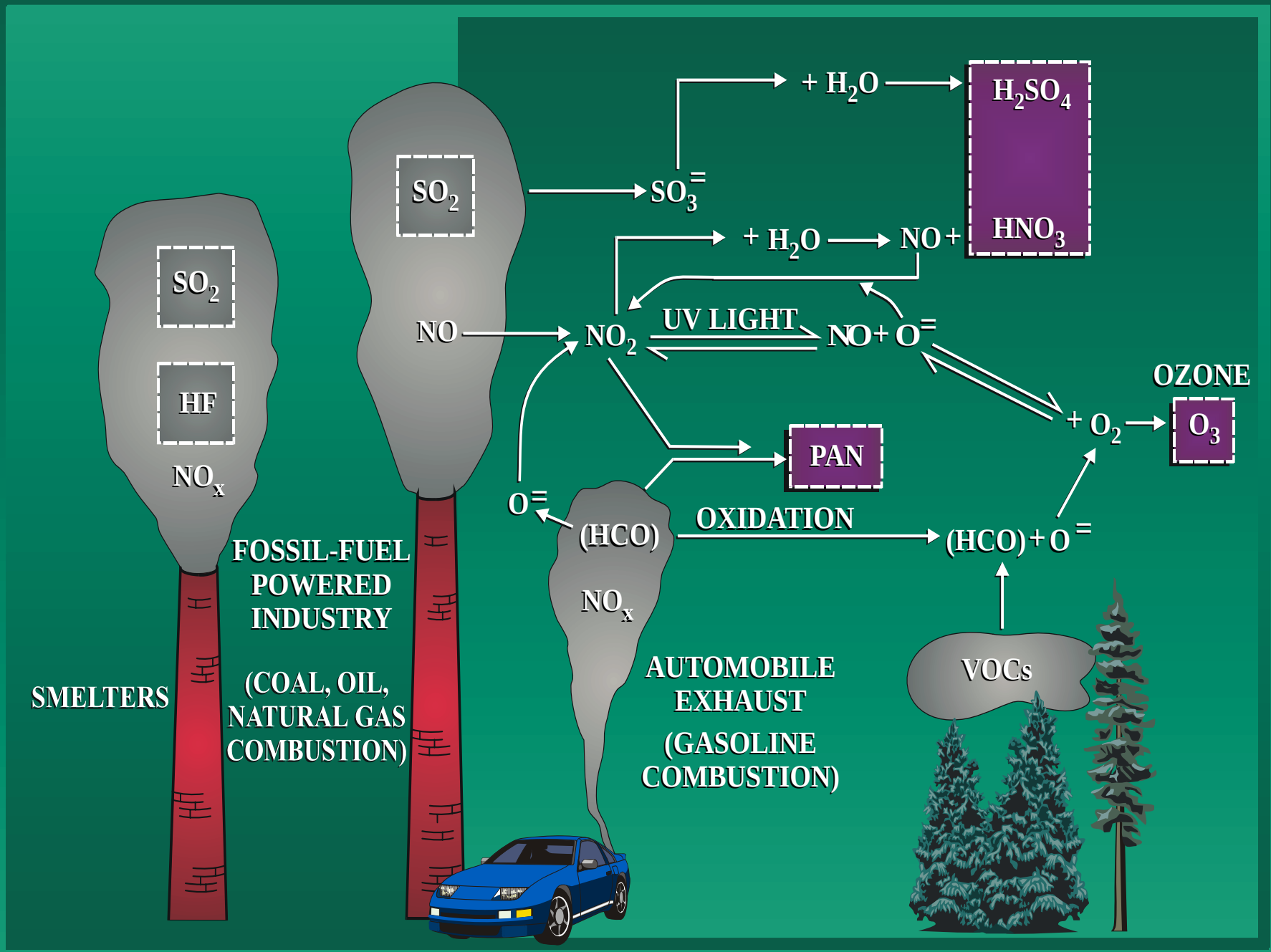
Ozone Exposure Overview



- Chemistry
- Patterns of diurnal variation
- Measured and modeled concentrations
- Effect of control strategies
- NPS trends analysis

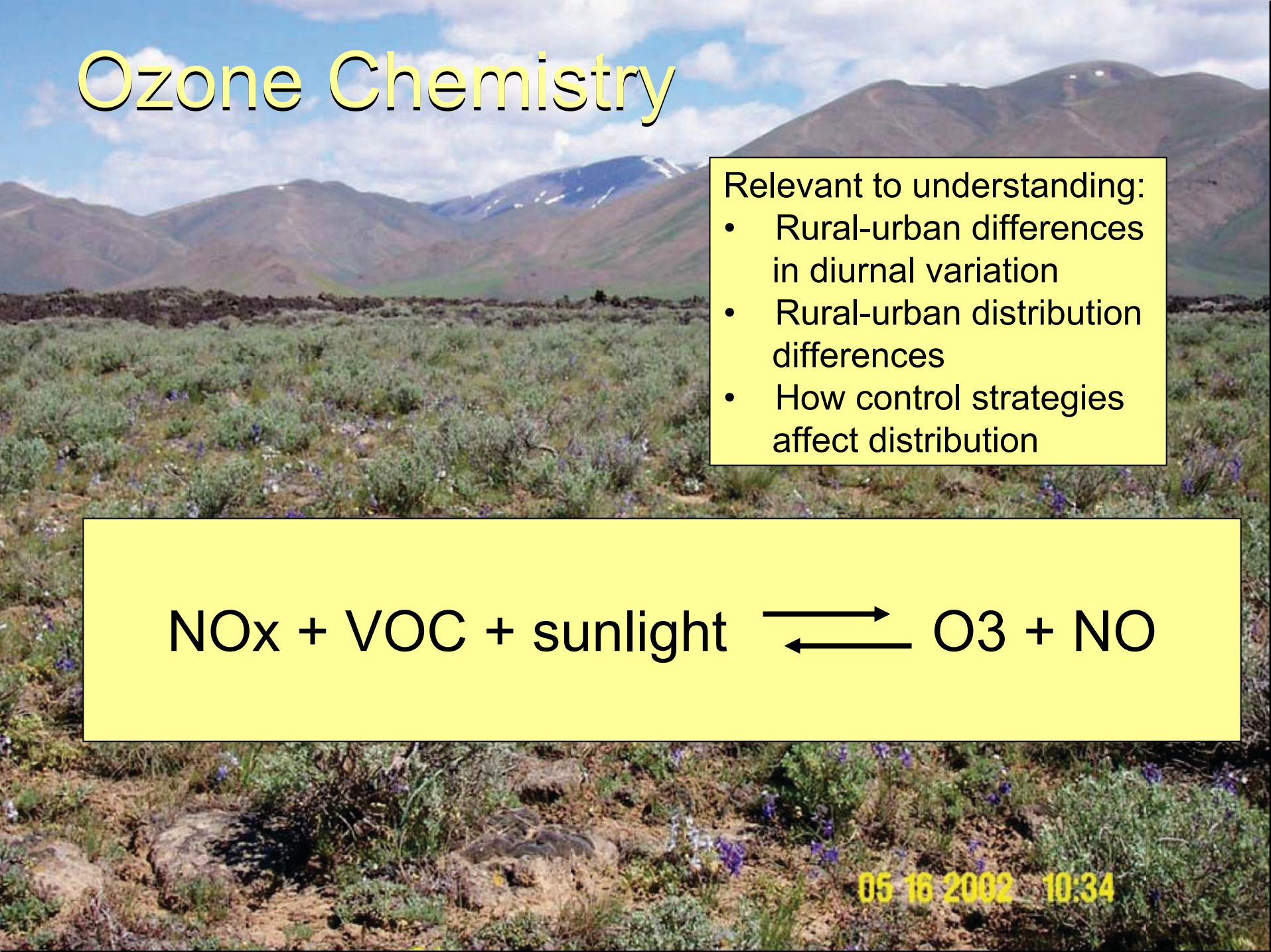

+ H_2O
H_2SO_4
SO_2
$SO_3^=$
+ H_2O
NO +
HNO_3
SO_2
NO
NO_2
UV LIGHT
NO + $O^=$
OZONE
HF
+ O_2
O_3
NO_x
PAN
$O^=$
(HCO)
OXIDATION
(HCO) + $O^=$
FOSSIL-FUEL POWERED INDUSTRY
NO_x
AUTOMOBILE EXHAUST (GASOLINE COMBUSTION)
VOCs
SMELTERS
(COAL, OIL, NATURAL GAS COMBUSTION)

Ozone Chemistry

Relevant to understanding:

- Rural-urban differences in diurnal variation
- Rural-urban distribution differences
- How control strategies affect distribution

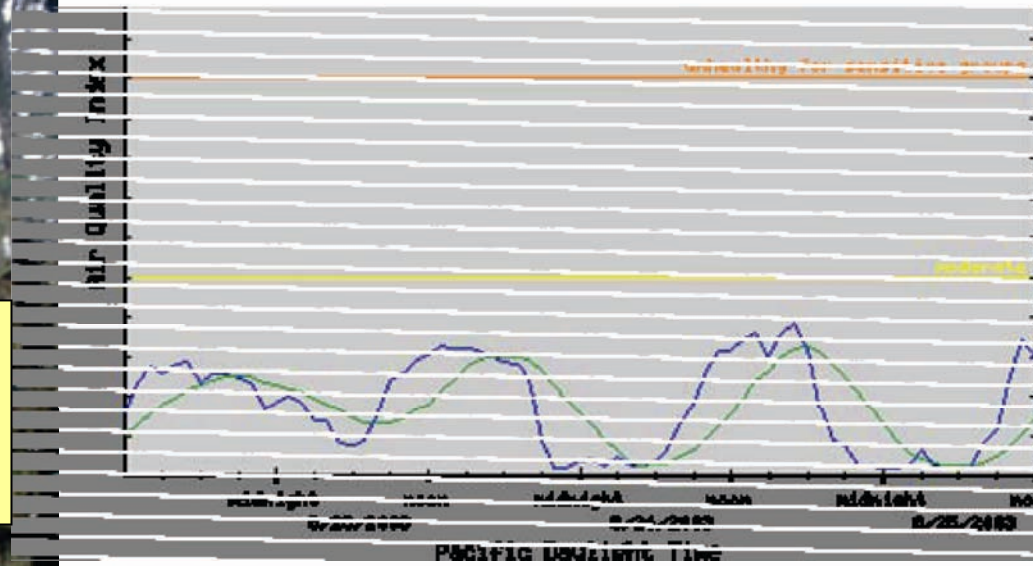
$$NOx + VOC + sunlight \rightleftharpoons O3 + NO$$

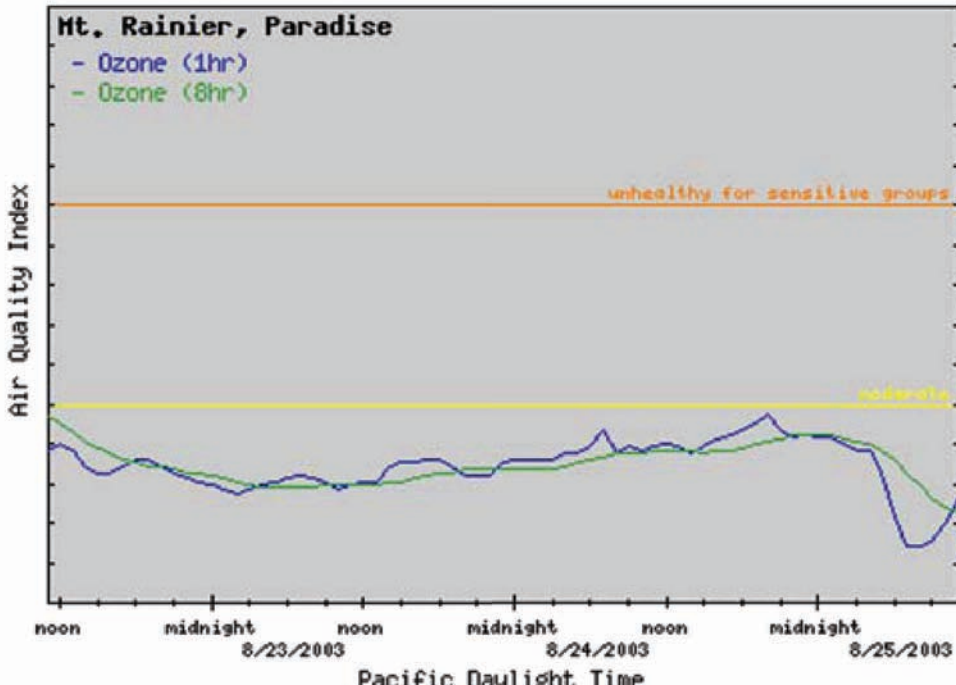


Ozone Chemistry – Effects on Diurnal Variation

Normal urban/suburban pattern -
NOx titration at night destroys O3

Mountain profile –
Less NOx titration (“pristine air”)
Better mixing – free troposphere





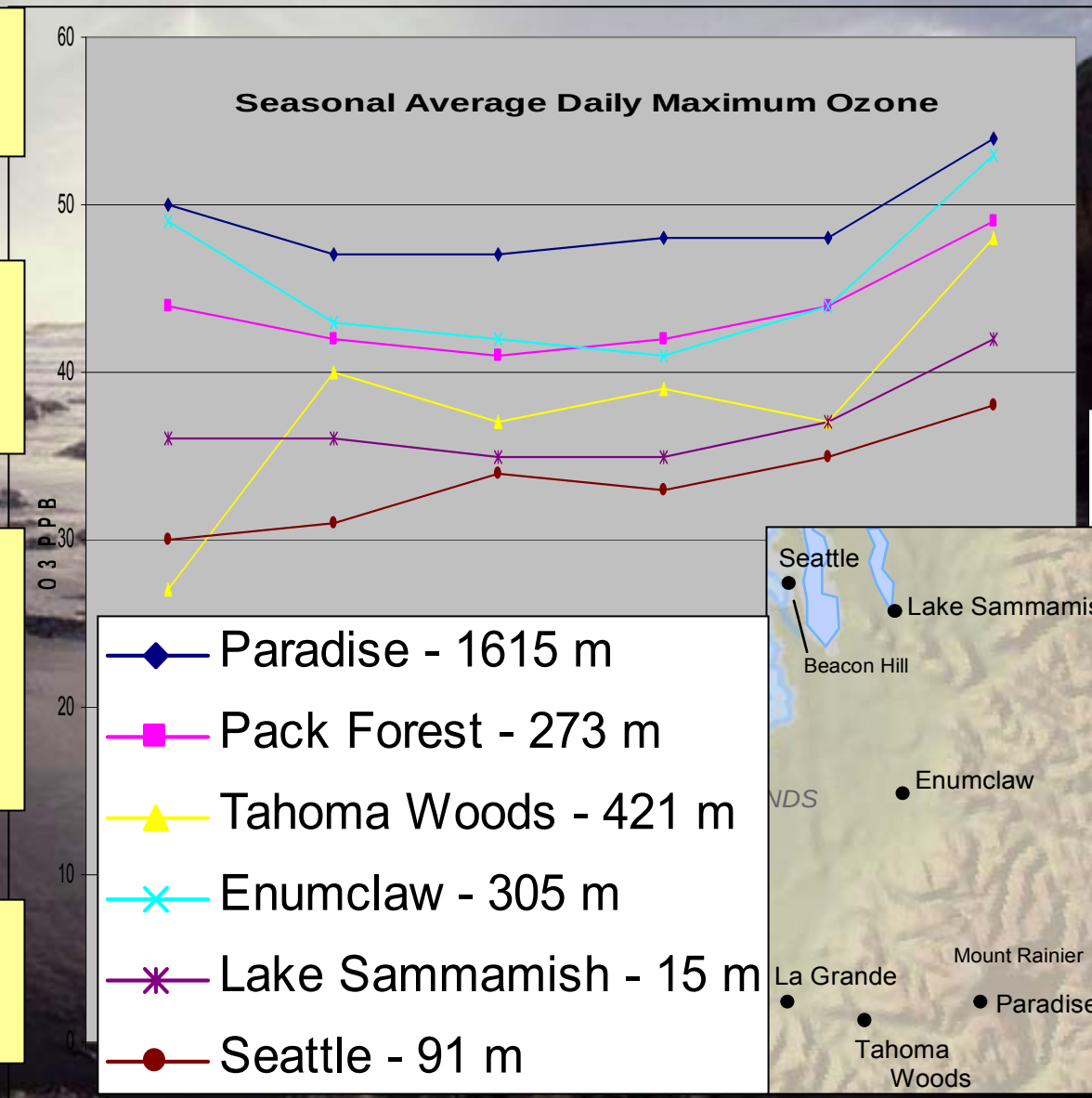
Ozone – Measured and Modeled Concentrations

Ozone forms downwind of precursor emissions.

Ozone increases 1.3 ppb/ 100 m increase in elevation (Cooper and Peterson, 2000)

Highest concentrations in Puget Sound measured down-wind and at highest elevation site – 5400 ft (EPA AirData)

Nearly all monitoring is at less than 300 m



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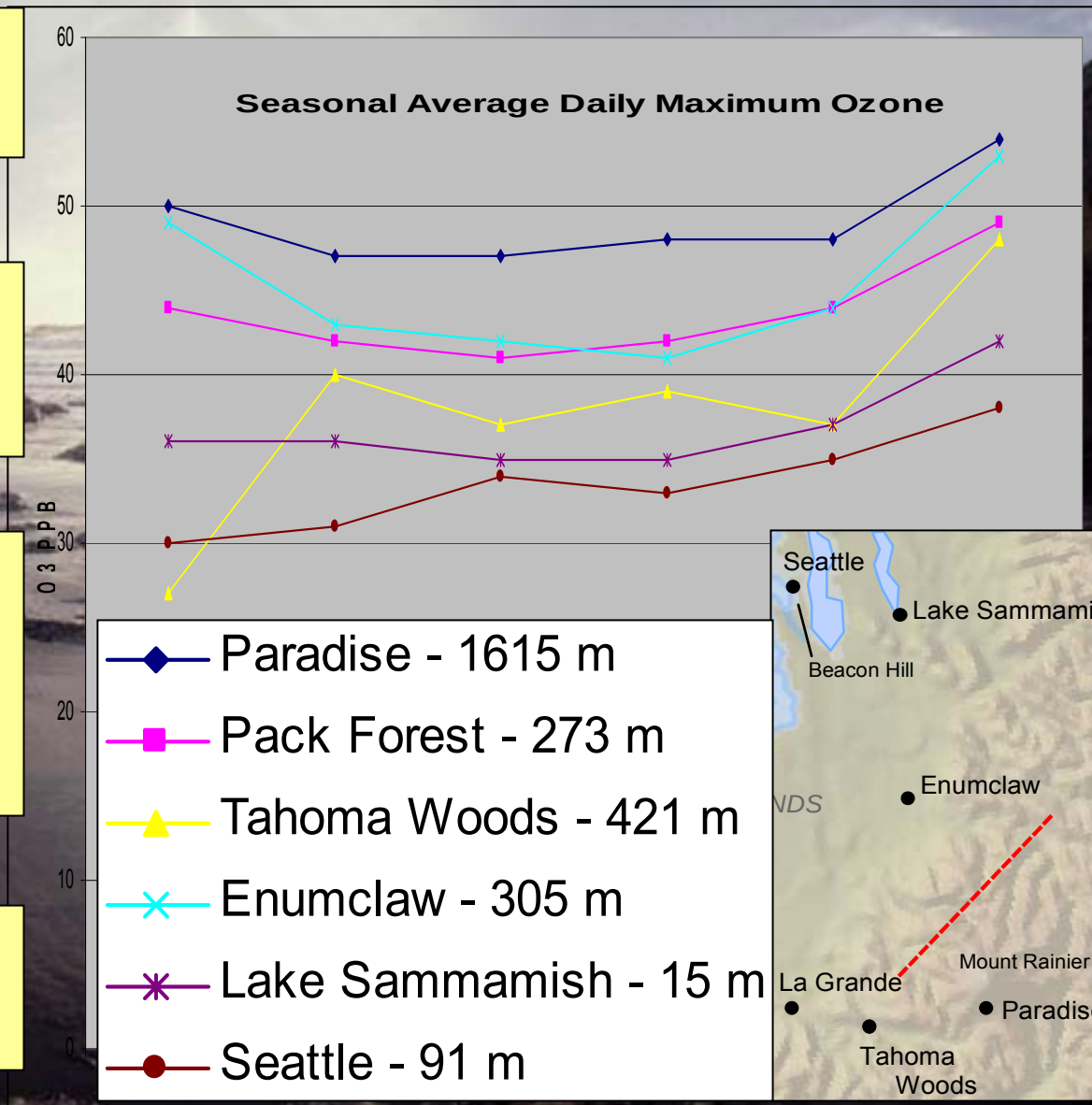


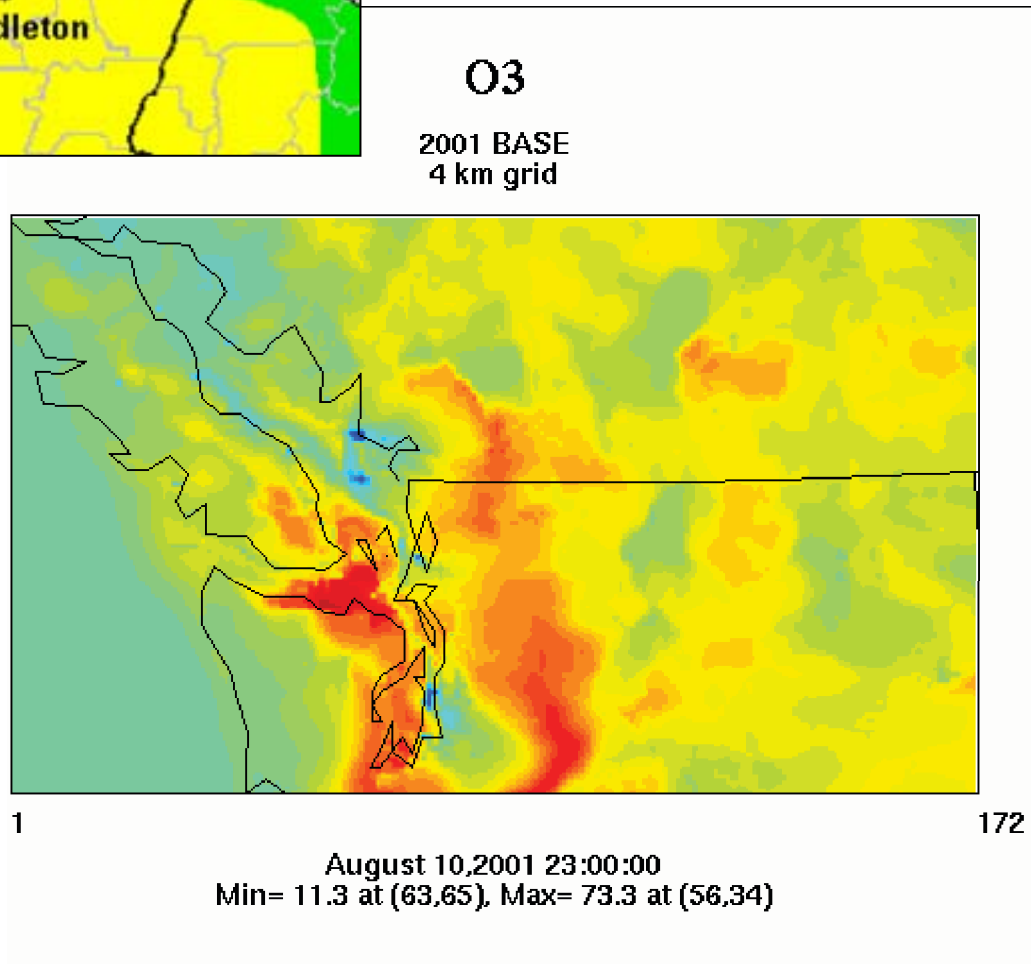
Ozone – Measured and Modeled Concentrations

- Other high elevation sites – Mount Baker, Mount Hood, Hurricane Ridge – likely to also have elevated concentrations based on modeling, passive ozone monitoring, and aircraft measurements (Barna, Peterson, Jaffe)

- In addition to the high elevation sites – modeling indicates potential hotspot over San Juan Island NHP (Georgia Basin/Puget Sound Airshed Characterization Report)

EPA map of monitored values (ozone exceedance at Paradise)

Environment Canada model (a “typical” day)



Ozone – Effect of Control Strategies

Ozone forms downwind of urban areas with highest concentrations in the foothills of the Cascades (Peterson, Barna)

- "When VOC emissions alone are reduced, the location of the peak ozone levels is shifted 40 km downwind to the SE, resulting in maxima occurring in the vicinity of the Paradise monitor on Mount Rainier" (Barna, et. al., 2001)
- "Decreased NOx emissions provide larger ozone reductions further downwind" (Barna, et. al., 2001)

"Predicted Air Quality During a Summer Day in 2009" by Otterson and Figueroa, 2004 (unpublished)

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Ozone Ecosystem Response

- Effects on sensitive vegetation
- Vegetation thresholds exceeded
- Effects on wildlife
- Global climate change

Ozone Effects on Sensitive Vegetation

- Reduced growth (antagonistic with nitrogen deposition)
- Early leaf senescence/needle drop (synergistic with nitrogen deposition)
- Shoot growth favored over root growth (synergistic with nitrogen deposition)
- Reduced resistance to drought, disease and insect predation (synergistic with nitrogen deposition)
- Visible foliar damage at high concentrations (synergistic with NOx/N deposition)

- All of which results in:
  - Changes in species composition and changes in species and community diversity
  - Increased fire risk
  - Increased risk of disease and insect predation
  - Reduced resiliency

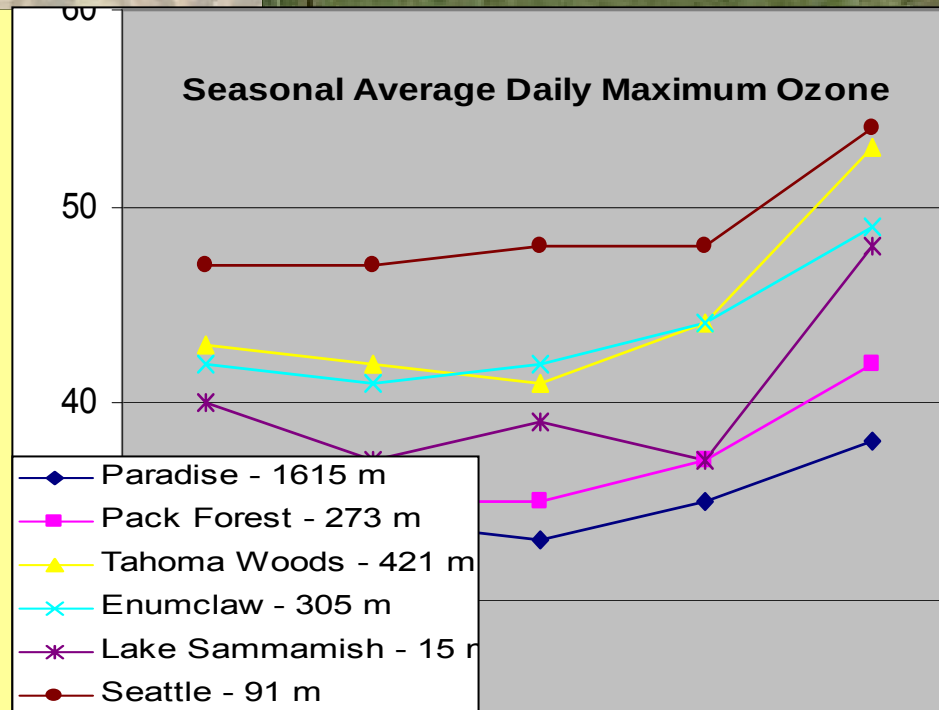
Vegetation Effects

Thresholds Exceeded

Concentrations at Tahoma Woods (elevation 421 m) are ecologically significant

SUM06 ≥ 8 W126 ≥ 5.9

What about other high elevation sites? Paradise? Hurricane Ridge? Mount Baker?



Ozone Effects on Wildlife

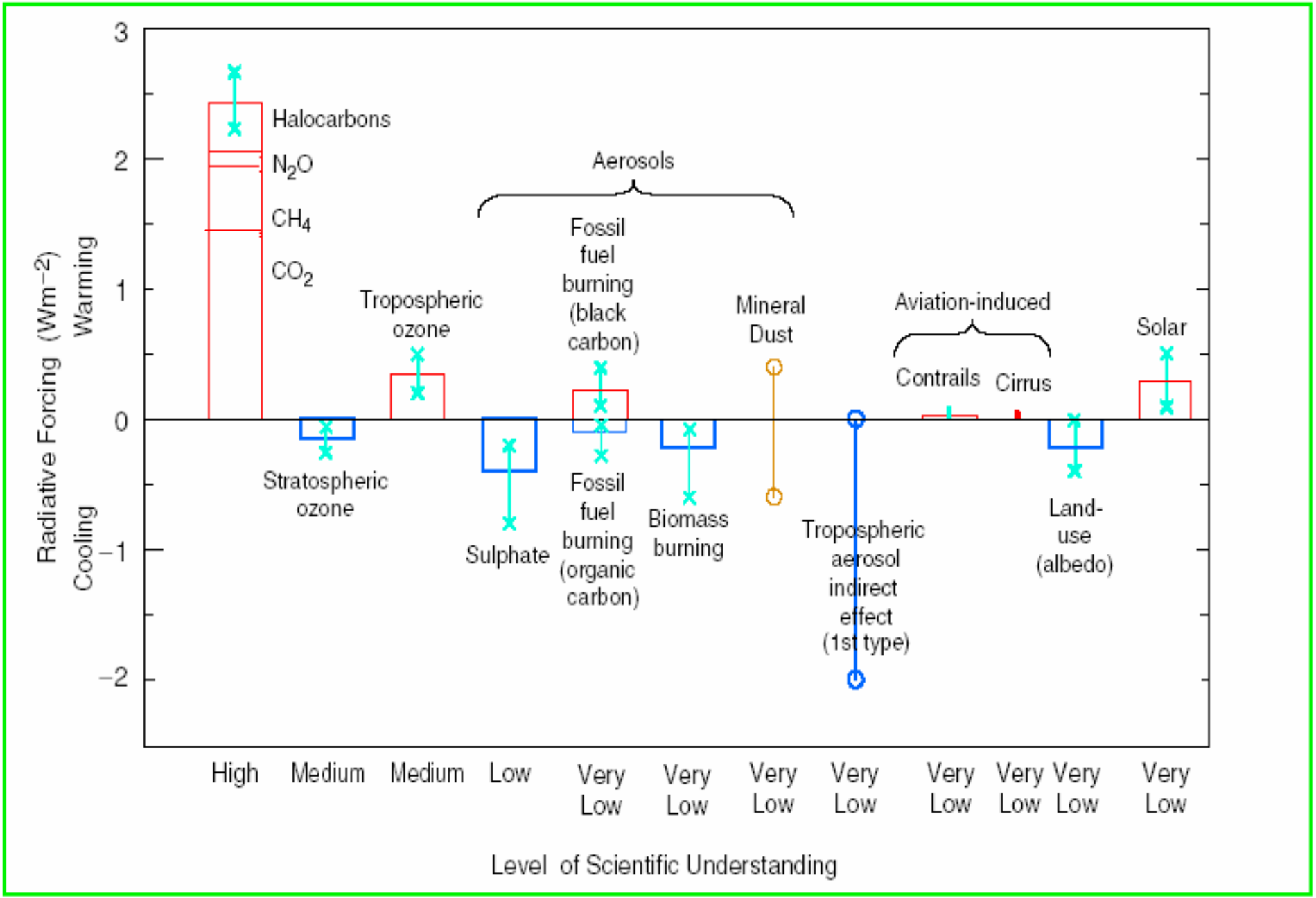
- Effects largely unknown
- Lack of diurnal variation may be significant
- Amphibians may be most sensitive

Global Climate Change

- Ozone is a greenhouse gas – rivaling methane in significance

- Global climate change projections:
  - Increased temperature
  - Increased stagnation events

  →increased ozone concentrations



http://www.ipcc.ch/pub/wg1TARtechsum.pdf

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Ozone Trends – FLM Perspective

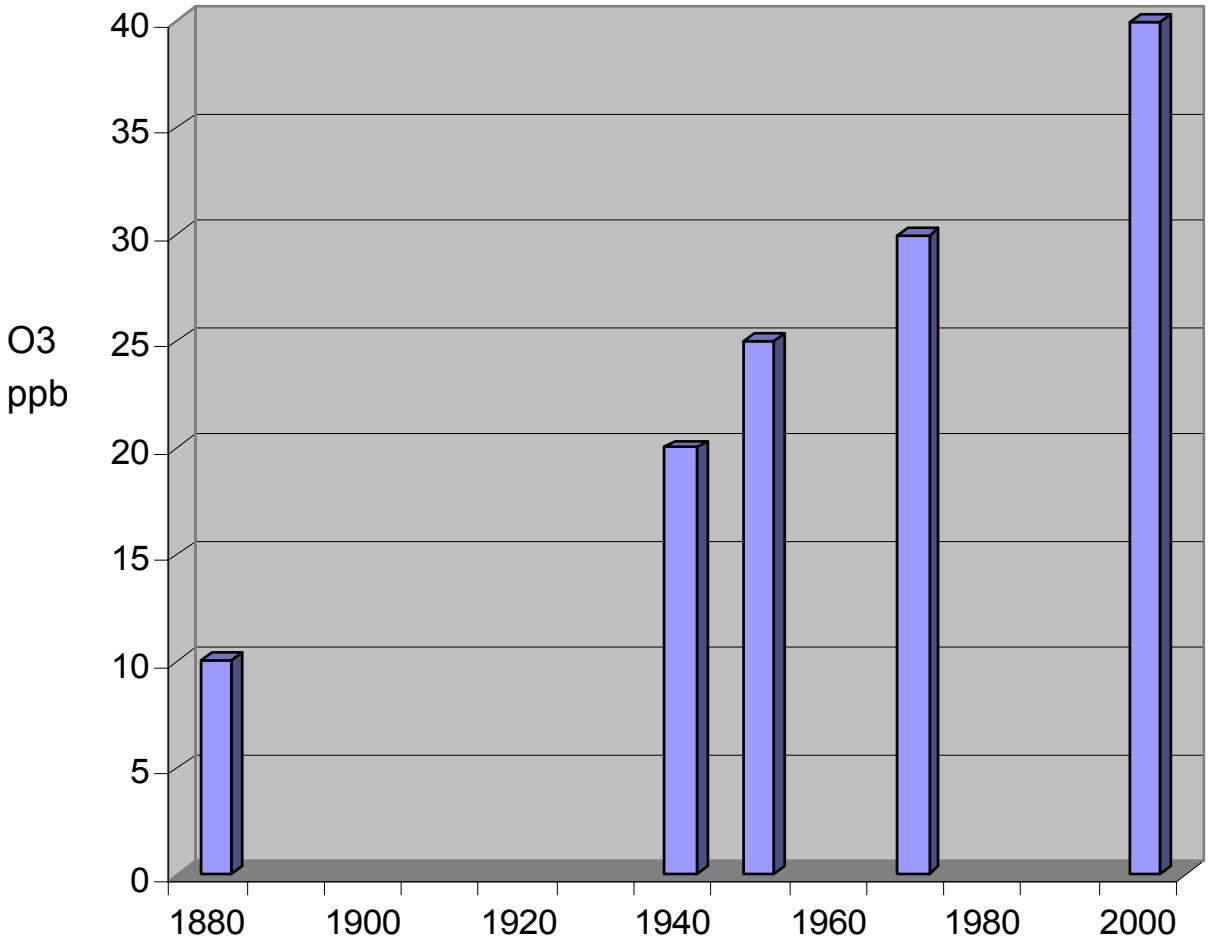
- NPS ozone trends analysis
- Precursor trends
  - Background concentrations
  - Long range transport
- Regional projections

NPS Trends Analysis

- Ozone concentrations showing no trend at Olympic and Mount Rainier NPs
- Ozone concentrations increasing at North Cascades and Craters of the Moon NPs
- Dan Jaffe, UW, states that the data from North Cascades NP provides a good indication of regional background ozone concentrations, modulated somewhat by local deposition and day-night variations

Precursor Trends - Background Concentrations

- Quadrupled since 1880 in the Northern Hemisphere

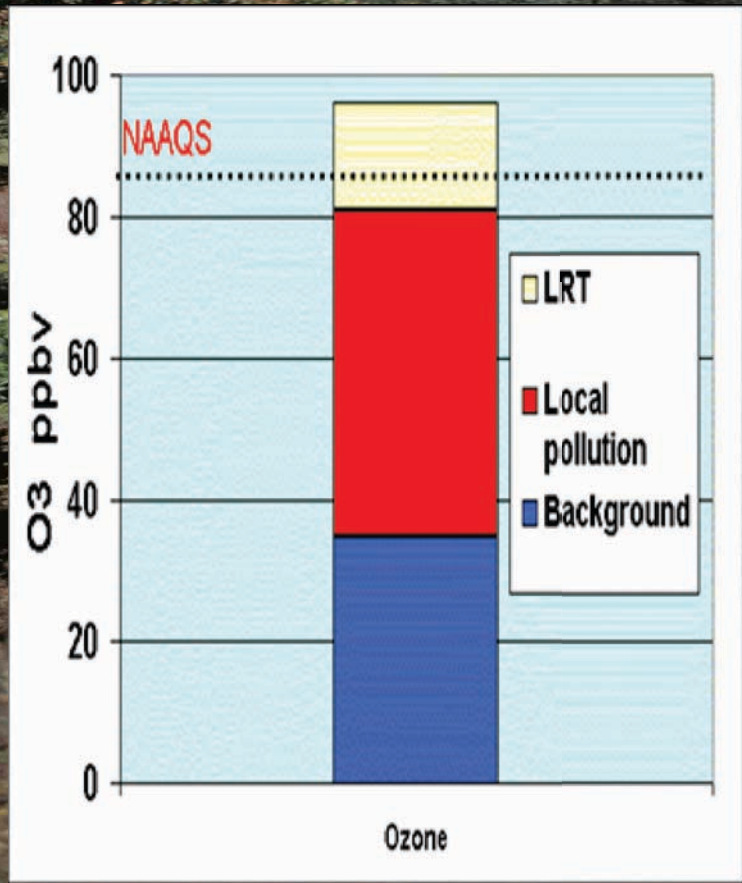


From Bytnerowicz, et. al. Environmental Pollution 130 (2004) 5-16

Precursor Emissions – Background Concentrations and Long Range Transport

- Asian contribution to background levels along the west coast have increased by 10 ppb – about 30% – in the past 18 years

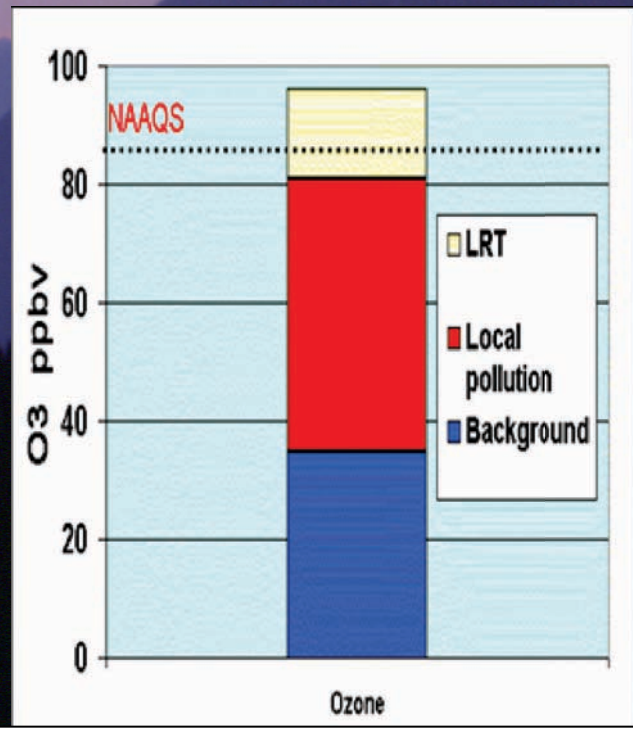
- PLUS - Long range transport events episodically increase ozone even more



(Jaffe, et. al., 2003; chart from a presentation by Parrish, NOAA)

Ozone Projection – FLM Perspective

- Decreasing precursor emissions due to various vehicle emission/fuel standards
- Increasing precursor emissions due to growth in:
  - Population
  - Marine vessel traffic
  - Intensive agriculture
- Increasing Asian emissions – background and long range transport events
- Increasing precursor emissions from wildfire (due to GCC, other stressors)
- Increasing ozone formation/concentration due to increasing temperatures, stagnation events (due to GCC)



Jaffe, et. al., Long-range transport of Siberian biomass burning emissions and impact on surface ozone in western North America

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Monitoring Challenges in National Parks

We want to monitor at high elevation where maximum pollution/deposition occurs but then we come up against:

- Wilderness
  - No roads
  - No power
  - Lots of critters
  - Lots of restrictions
- Mountains
  - Lots of wind
  - Lots of ice
  - Lots of snow

So…the monitors go where there's access, power, less extreme conditions, and few regulatory restrictions – often the low elevation administration office or visitor center

Hope for the future?

- Solar power
- Satellite link
- Calibrated at beginning and end of season

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Questions?