Environment Canada Environnement Canada

Environmental Impacts of Air Pollution

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Environment Canada's Green Lane (www.ec.gc.ca)
Clean Air Online (http://www.ec.gc.ca/cleanair-airpur)
2004 Canadian Acid Deposition Science Assessment (www.msc-smc.ec.gc.ca/saib/**acid**/**acid**_e.html)

Why is the Atmosphere Important?

- the atmosphere affects all exposed surfaces all the time
- the atmosphere is highly variable in space and time
- no other medium can transport great amounts of pollutant over such large distances over so short a time

Image courtesy NASA:
http://veimages.gsfc.nasa.gov//5417/ECanada.A2003144.1535.1km.jpg

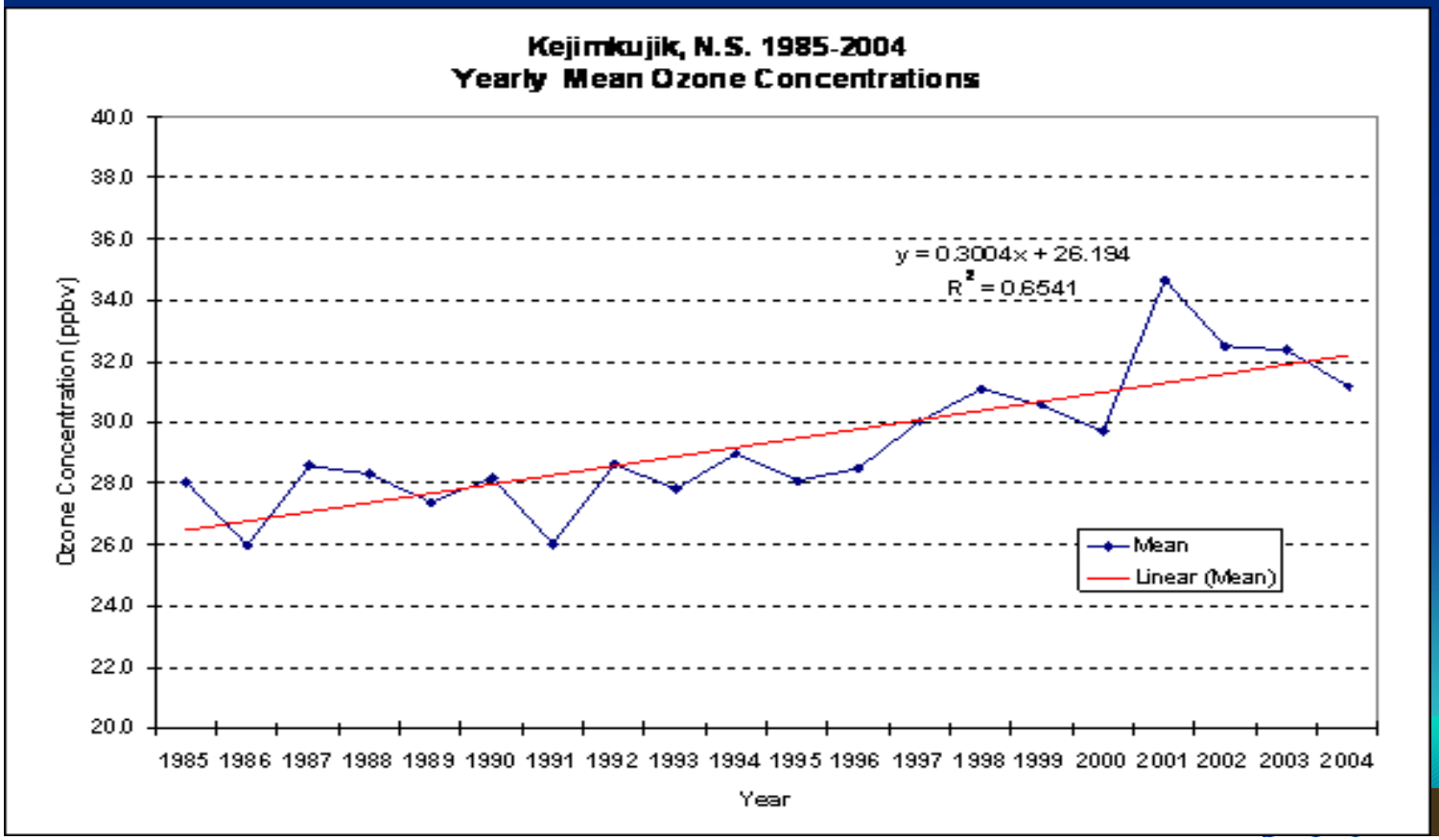
How does air pollution affect the quality of the environment?

- Ozone, PM
- Acid Deposition
- Hazardous Air Pollutants (HMs, POPs)
- Increased UV due to depleting ozone layer
- Indirect Effects (biofeedback cycles)

SMOG (ozone and PM)

Ground-Level Ozone:

- photochemical reaction between NOx and VOCs
- strong oxidant
- causes tissue damage, reduced growth rate



Ozone Damage

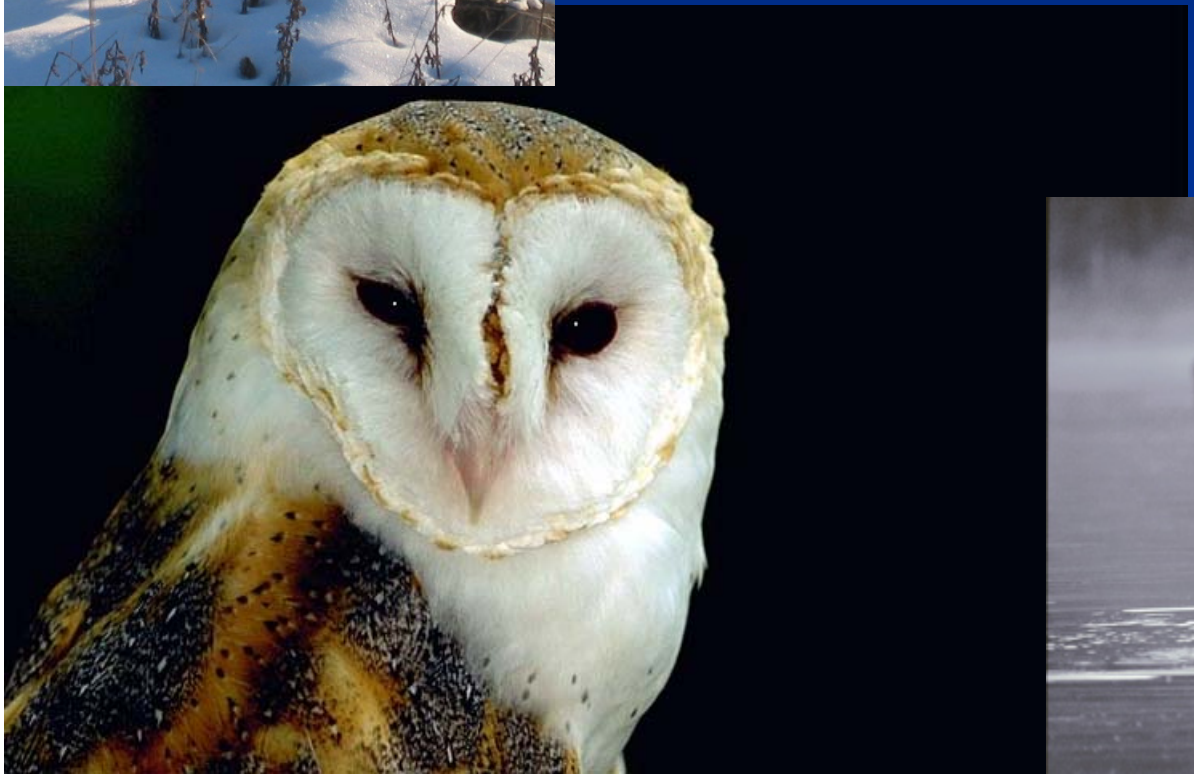
The first sign of ozone damage in vegetation is a purple or black stippling between the veins in the tops of the leaves

ozone enters stomata with CO_2, prompting stomata to close which also blocks CO_2, interfering with photosynthesis

Particulate Matter (PM):

- primarily physical damage (tissue)
- inhalation causes respiratory and cardiac problems, premature death

secondary issues:
- acidic (sulphates, nitrates)
- toxic (HMs, PAHs)



-much research focus on human health effects... speculate similar effects in wildlife

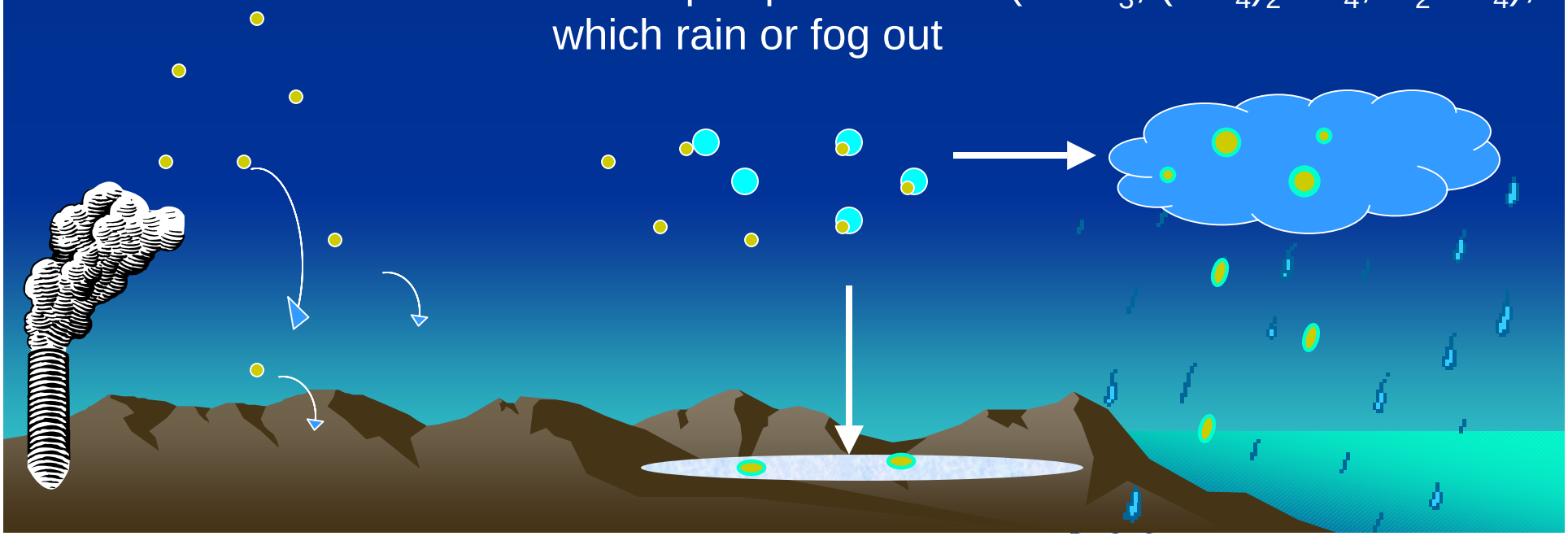
Acid Deposition

Dry Deposition

direct deposition of acidic gasses (NO_x, SO_2, H_2SO_4) and acid particulate (HNO_3, $(NH_4)_2SO_4$, H_2SO_4), to leaves, rocks, buildings

Wet Deposition

acidic gasses react with water in the atmosphere to form liquid phase acids (HNO_3, $(NH_4)_2SO_4$, H_2SO_4), which rain or fog out



- Acids are strong oxidants causing physical damage to tissues

- Deposition of H_2SO_4 can yield the following reactions in soils and water:

$$H_2SO_{4(aq)} \longrightarrow 2H^+ + SO_4^{2-}$$

$$CaCO_{3(aq)} \longrightarrow Ca^{2+} + CO_3^{2-}$$

$$2H^+ + CO_3^{2-} \longrightarrow H_2O + CO_2$$

- if the soil has high carbonate content, this reaction will buffer the acidity. However once $CaCO_3$ has been depleted by this reaction, buffering capacity is lost and the ecosystem will become acidified

- effect most evident during spring melt when the pollutants that have built up in snow and frozen ground all drain to aquatic basin at once – especially important if biota are in vulnerable stage in the spring time (hatchlings)

CRITICAL LOAD

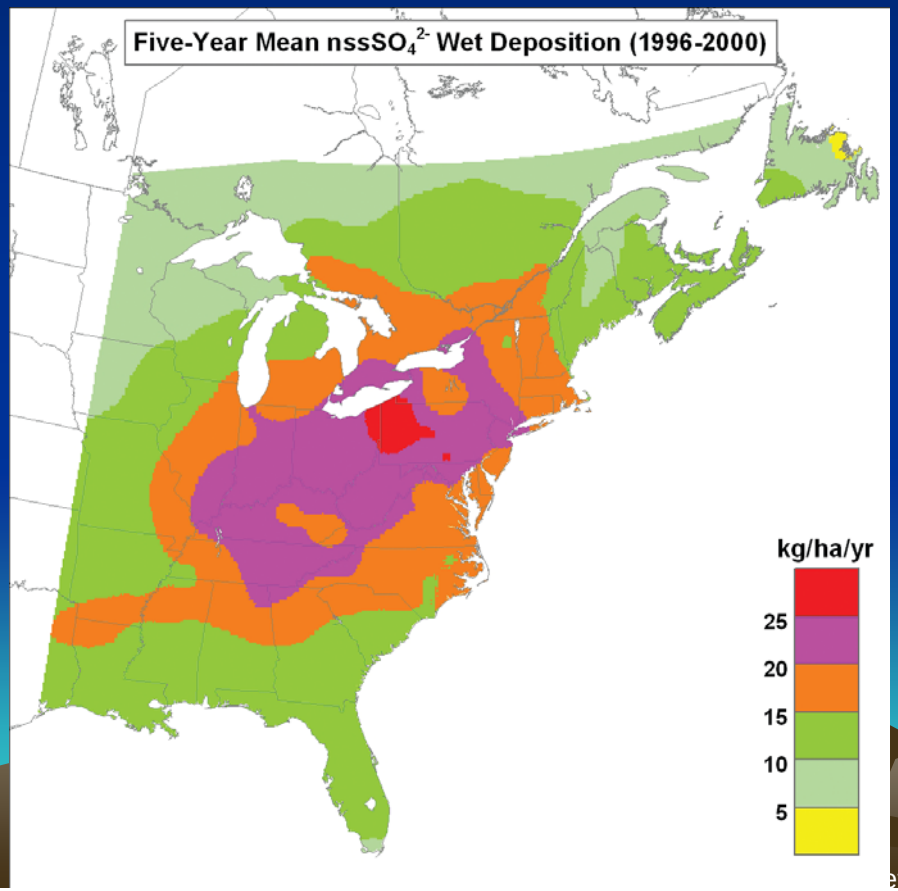
- amount of pollution that an ecosystem can tolerate – above which the environment is harmed
- dependent on the ability of the ecosystem to neutralise acidity

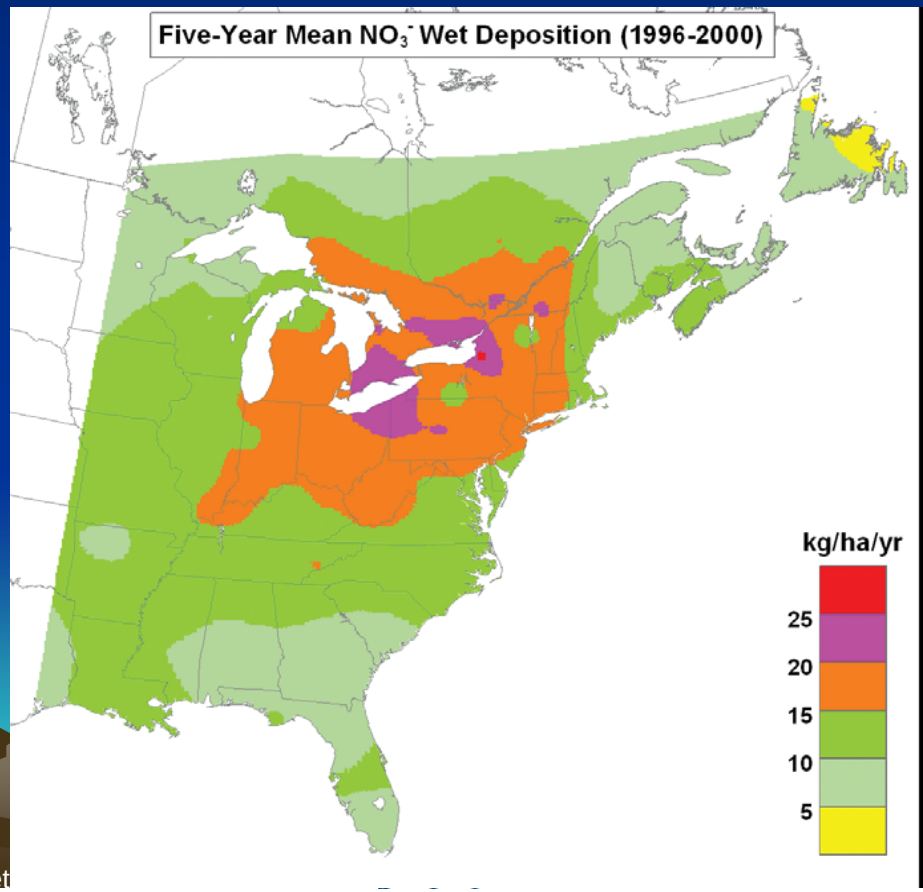
TARGET LOAD

- amount of pollution that is deemed achievable and politically acceptable
- dependent on environmental considerations as well as ethics, scientific uncertainties, social and economic effects

in 1994 the target load for wet sulphate deposition was set by the Eastern Canada Acid Rain Program at 20 kg/ha/yr from Manitoba eastwards

(through reductions in SO_2 emissions)





Meteorological Service of Canada, 2004

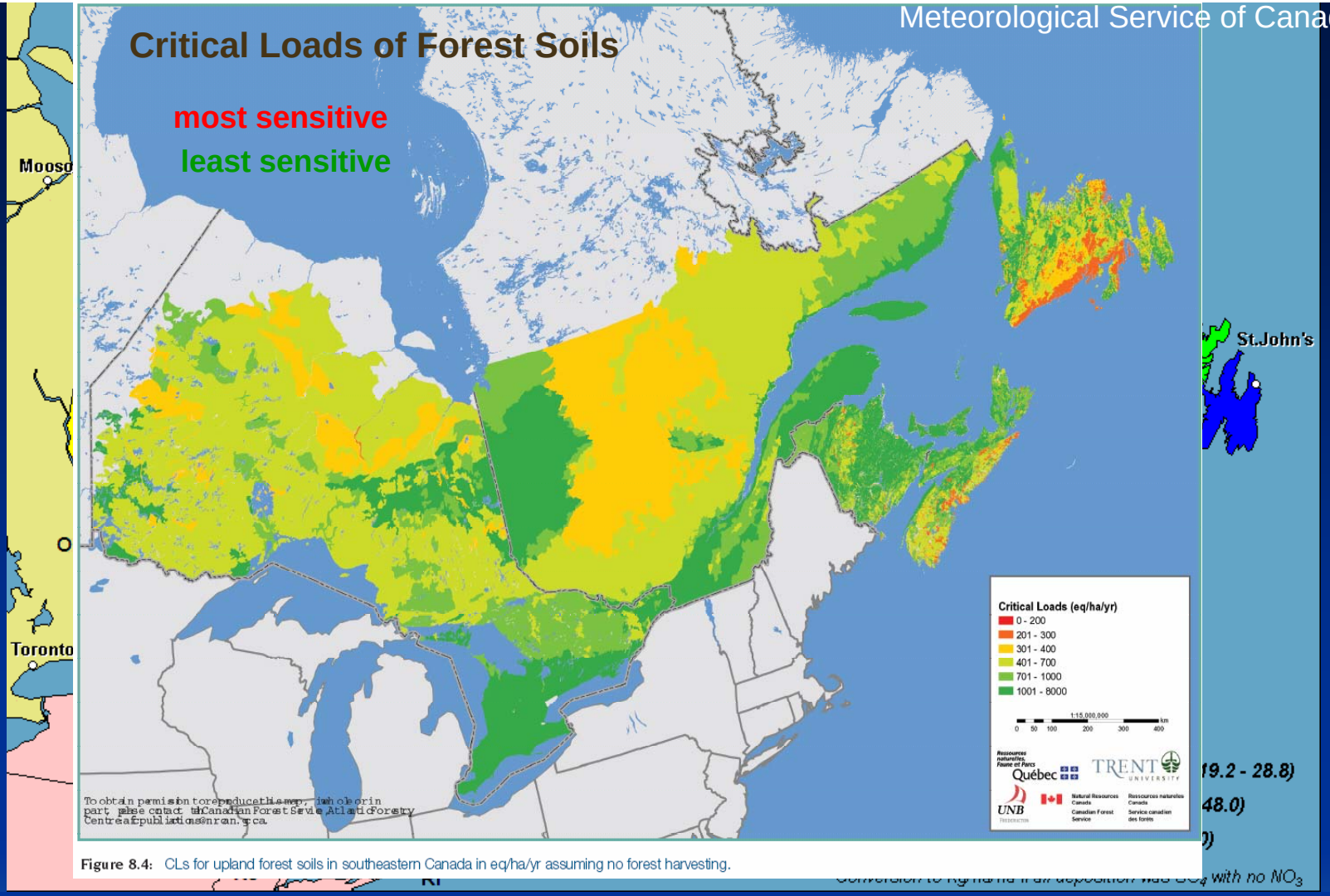


Figure 8.4: CLs for upland forest soils in southeastern Canada in eq/ha/yr assuming no forest harvesting.

The critical loads remain much lower than the 1994 target loads, and 21-75% of Eastern Canada still have acid deposition rates in excess of critical loads

Thus in 2000, the Canada-Wide Acid Rain Strategy adopted the primary goal of reaching critical loads across country

Biological Effects of Acidification

Fish:

- corrodes gill material, attacks $CaCO_3$ skeleton
- failure of females to spawn, and hatchlings or small fry unable to withstand acidity (thus some lakes only have older fish – leading to a false sense of ecosystem health for anglers who catch good-sized fish)
- uptake of HM pollutants
- decreased growth rate, inability to self-regulate body chemistry, reduced egg deposition, deformities, increased susceptibility to disease
- Atlantic Salmon stocks in SW NS declined 75% between 1975 and 2000; extirpated or declined >90% in 34 of 63 rivers in NS (Meteorological Service of Canada, 2004)
- least tolerant: trout, salmon, smallmouth bass, walleye
- most tolerant: yellow perch, rock bass, central mudminnow, largemouth bass

Biological Effects of Acidification

Birds:

- reduced fish stocks → loss of food source, esp for chicks
- leaching of heavy metals (HMs) → mercury (Hg) and lead (Pb) bioaccumulate in food chain, reaching toxic levels in piscavores
- loss of calcium-rich foods required by some bird species (i.e. wood thrush, black-throated blue warbler)

Hame, R.S., *Proceedings of the National Academy of Sciences*, Vol.99, No. 16, 2002

Biological Effects of Acidification

Forests:

- leeches out nutrients like Ca^{2+}, Mg^{2+}, K^{+} by combining with acids, leaving soil low in nutrients and eventually acidifying soil
- acid rain, fog, and vapour damages the surfaces of leaves and needles
- reduces tree's ability to withstand cold and disease

- inhibits germination and reproduction
- leads to loss of habitat and food sources … the effects move through the ecosystem

Biological Effects of Acidification

Eutrophication:

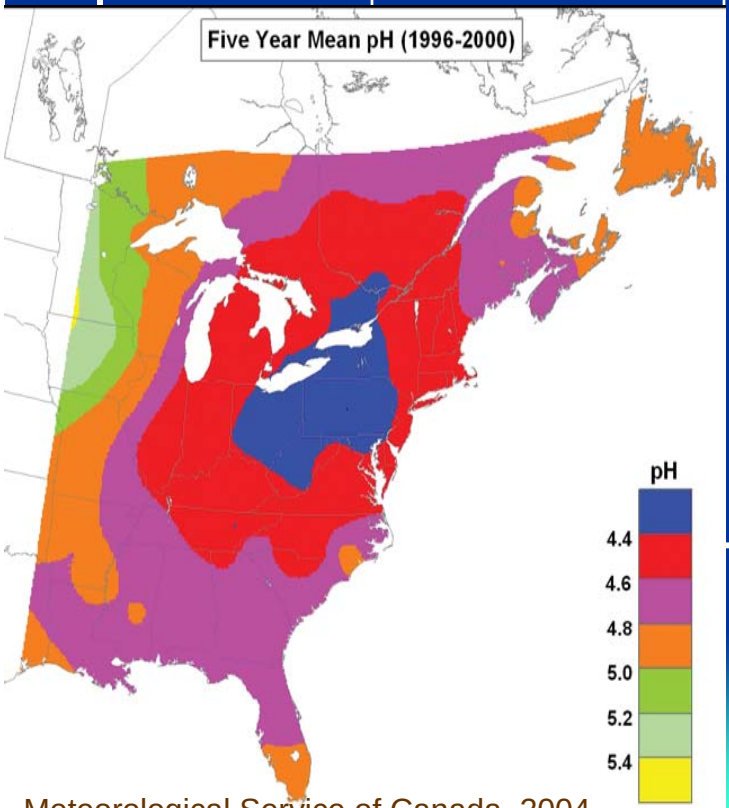
• Deposition of NH_4^+ and NO_3^- contributes to acidification, but also *fertilizes* soils by providing directly assimilable nitrogen

• The excess nutrients result in an over-fertilization and lead to *eutrophication*

• Eutrophication can result in an accumulation of algae in surface waters, suppressing the supply of oxygen to deeper waters, altering the ecology of the lake or bay

pH 14		7	5.6	4-5	0
basic		neutral	clean rain	acidic rain	acidic

pH	6.0	5.0	<5.0
Effects	• crustaceans, insects, some plankton begin to disappear	• major changes in the makeup of the plankton community • less desirable species of mosses and plankton invade • progressive loss of some fish populations is likely, with more highly valued species generally least tolerant of acidity	• water is largely devoid of fish • nearshore areas may be dominated by mosses • terrestrial animals, dependent on aquatic ecosystems, are affected



Meteorological Service of Canada, 2004

Clean Air Online (http://www.ec.gc.ca/cleanair-airpur)

THE SAD TRUTH:

many ecosystems in Eastern Canada may not recover without remedial measures because buffering capacity is entirely lost due to leaching of Ca^{2+} and other cations

so...is the acid rain problem solved?

Hazardous Air Pollutants (HAPs)

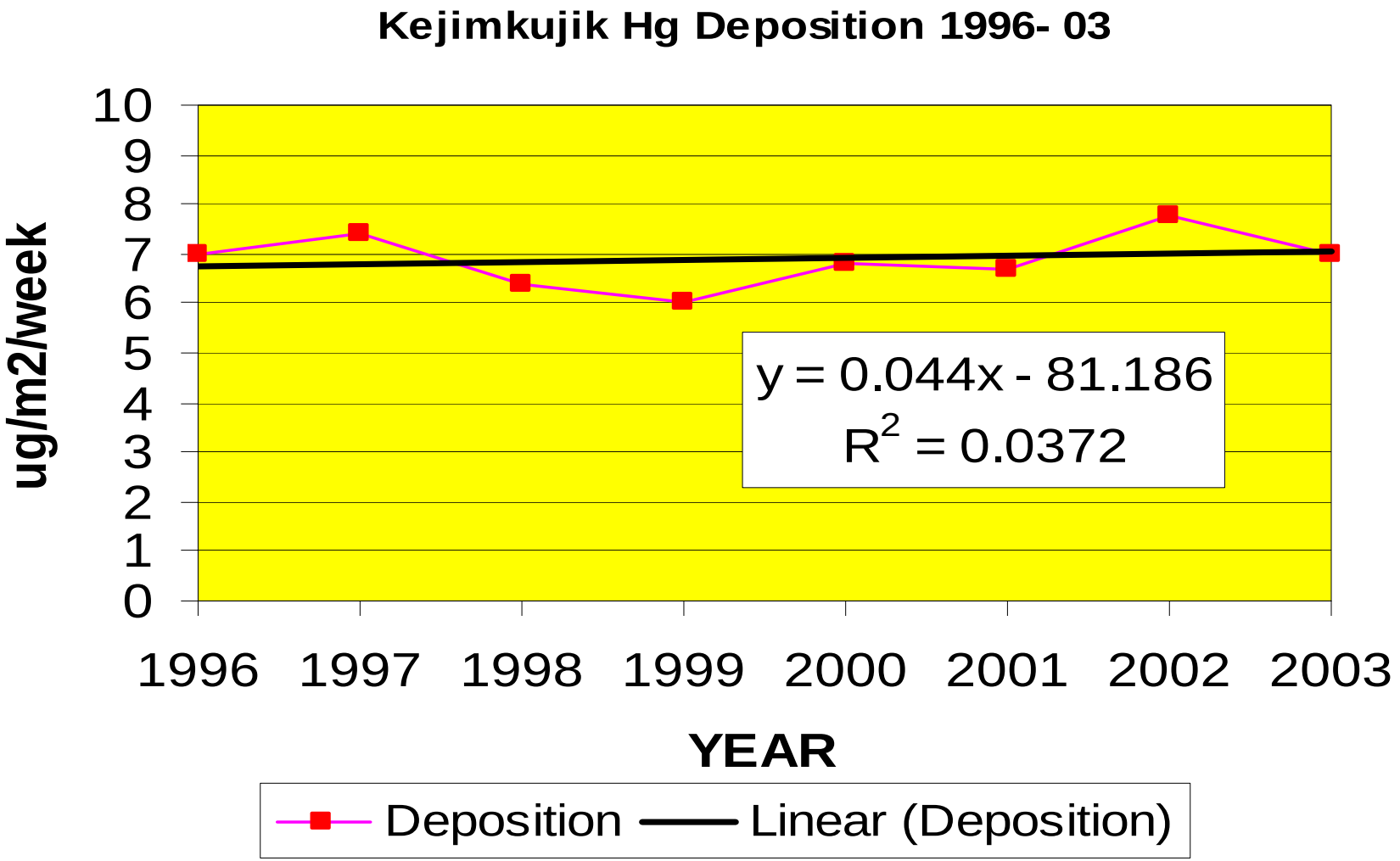
- POPs:
  - bioaccumulative and persistent in ecosystem
  - chronically or acutely toxic
  - Pesticides - DDT, chlordane, toxaphene
    - carcinogens, mutagens, teratogens, endocrine disrupters
  - dioxins, furans, PCBs – carcinogens
- Heavy Metals (HMs) – Hg, Cd, Pb, Al
- usually carried on fine particulate ($PM_{2.5}$)
- loss of ecosystem health and biodiversity

Mercury and Loons

- Hg is a neuro-poison, attaching myelin sheath of nerves, inhibiting neural transmission
- Initial effects are lethargy and reduction in interactive behaviour
- Loons: back-riding stops; preening increases → energy expenditure, increased mortality
- Hg impairs loon's reproductive success, cause growth-related problems, and death
- Loon chicks survival at Keji 0.25/pr vs 0.6/pr elsewhere

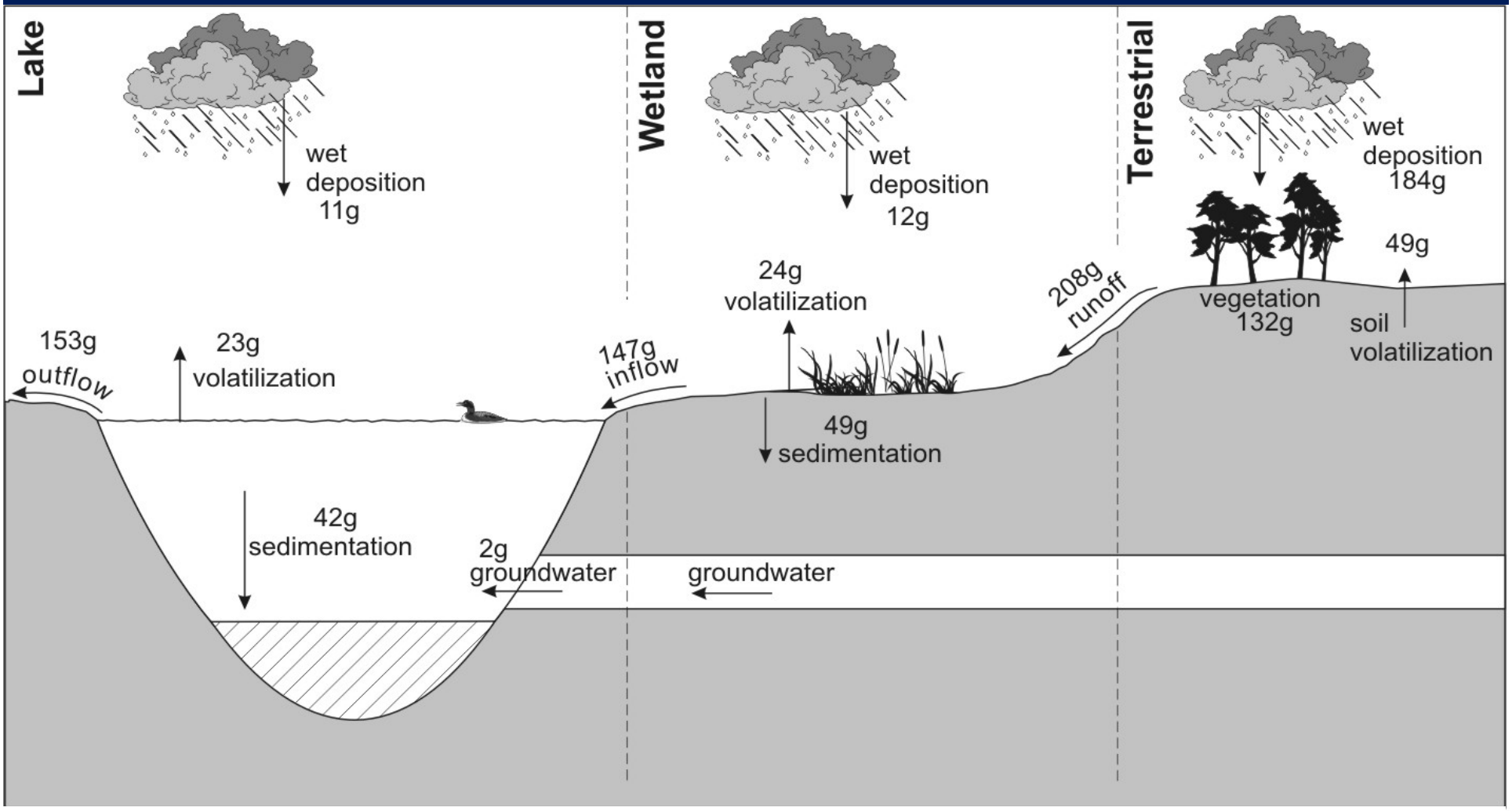
Nocera and Taylor, 1998.

TGM emissions cut by 50% but not seeing effects at Kejimkujik



Tordon et al, 2005

Biogeochemical Cycling of Hg



O'Driscoll et al., 2005

Methyl mercury

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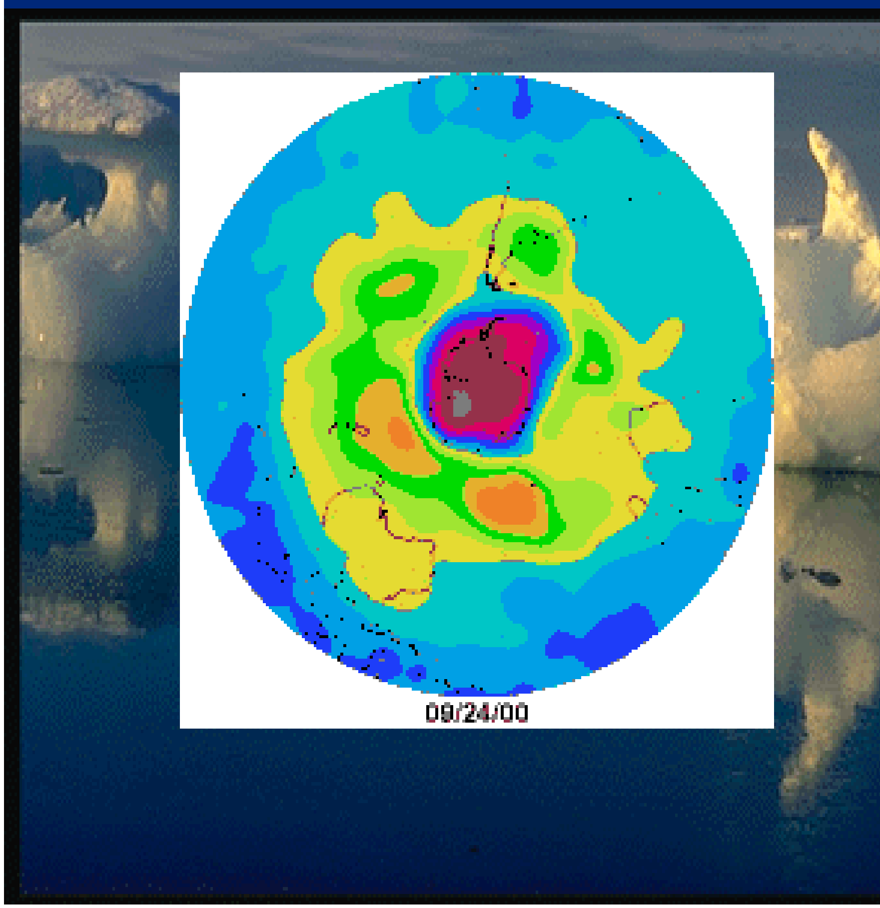
Ozone Layer

- ozone destruction by ozone depleting chemicals (CFCs, HCl)
- increased penetration of UV radiation
- increased tissue damage by UV; suspected cause of deformities
- changes in photochemical and biological production



• UV affects terrestrial and aquatic ecosystems, altering growth, food chains and biochemical cycles

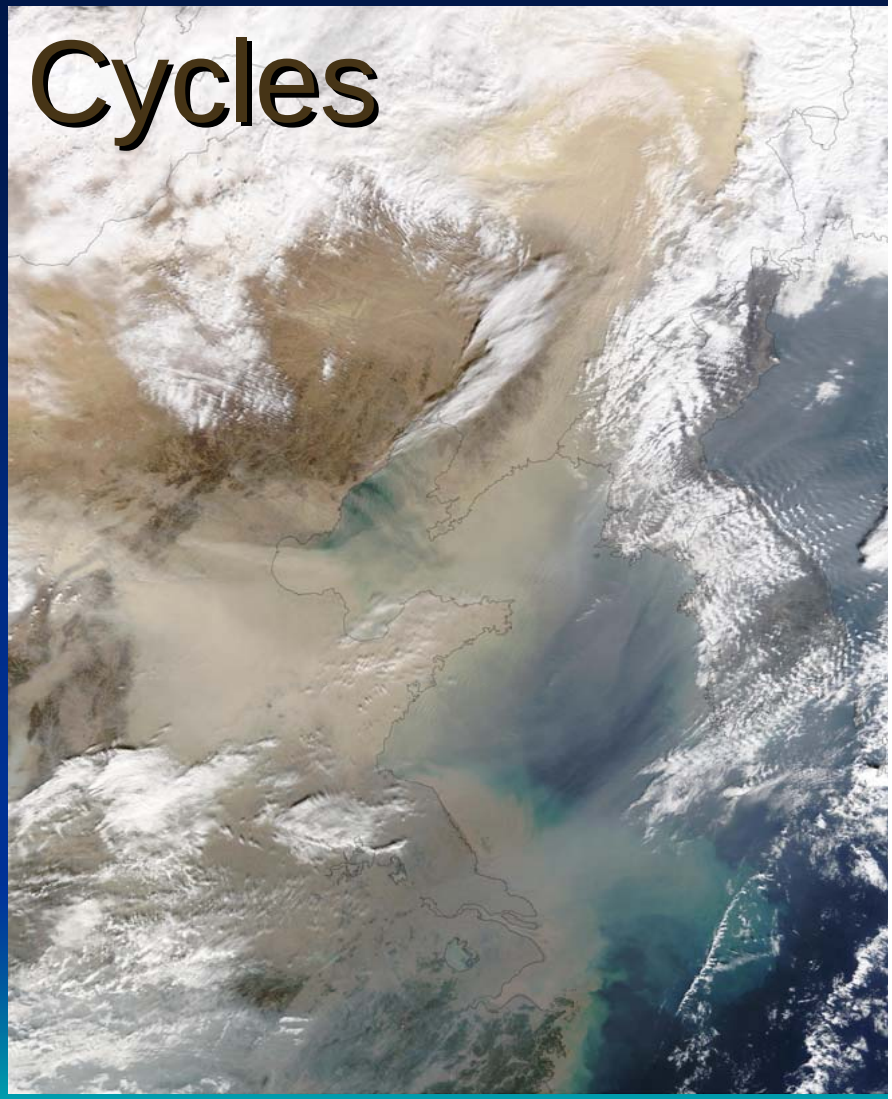
increased levels of UV-B radiation in the Antarctic result in impairment of metabolic processes, decreases in growth, reduction in
abnormalities, genetic damage, and death

• some species are more tolerant to UV and will proliferate while other less tolerant species will be adversely affected, altering the ecosystem

Feedback Cycles

more phytoplankton → higher albedo → cooling climate → changing ecology

- warming climate → plankton changes
- UV → plankton changes



Images from NASA's Terra Satellite

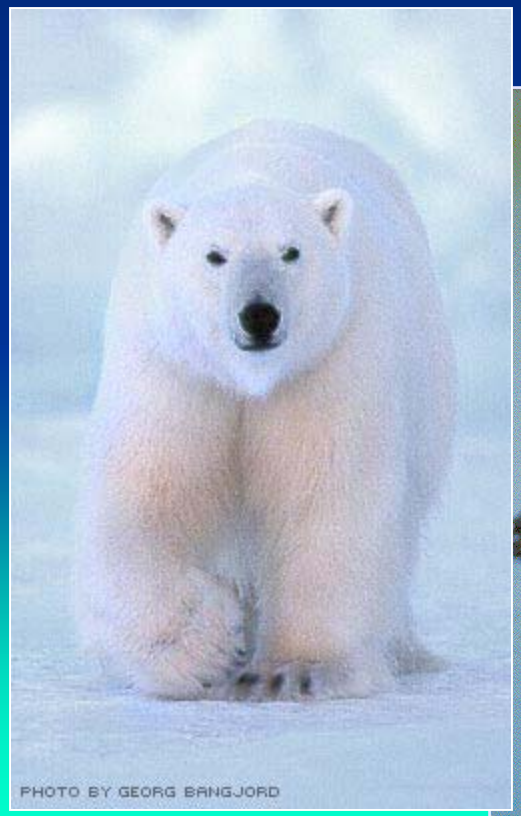
- SO_2 pollution may increase iron bioavailability

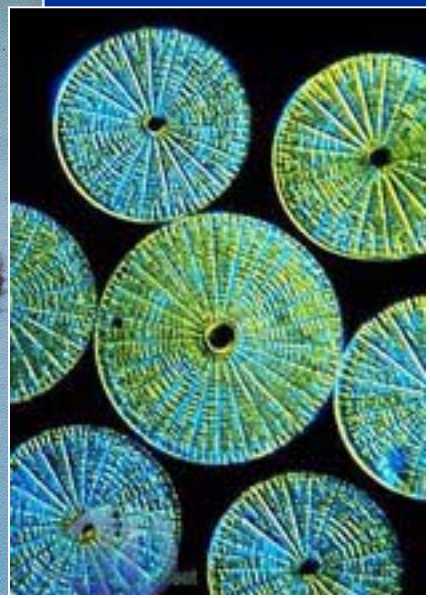
Biodiversity (species at risk)

-atmospheric chemistry means little if it cannot be related to impacts on ecosystem and/or human health

-atmospheric issues are thought to be the second most important stressors on biota (second only to land use changes)

-there will be winners and losers due to stressors, changing the ecology and threatening biodiversity





References and Useful Sites:

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2004 Canadian Acid Deposition Science Assessment www.msc-smc.ec.gc.ca/saib/**acid**/**acid**_e.html

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