

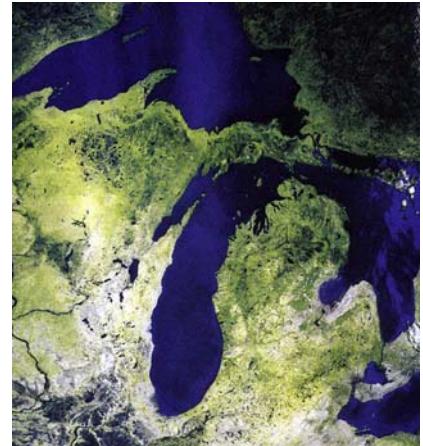
# The Global Water Cycle

*Accounting, Cycling, and Controls*

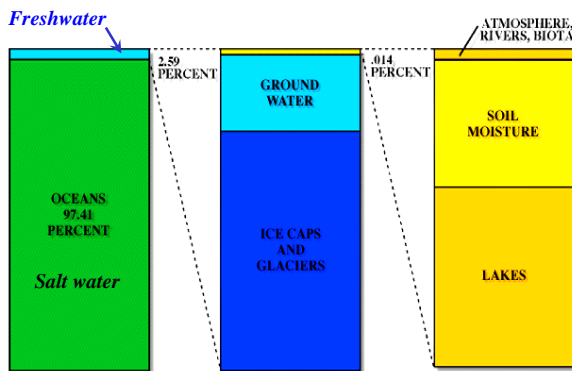
**(1) Accounting:**

<u>Location</u>	<u>Amount</u> (km <sup>3</sup> x 10 <sup>6</sup> )
Rocks (unavailable)	150
Oceans	1,350
Ice	27.5
Groundwater	15.3
Lakes and Rivers	0.025
Atmosphere (vapor)	0.013

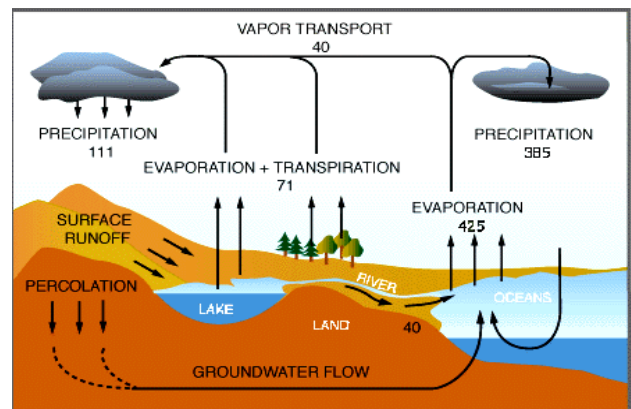
The Laurentian Great Lakes contain ~20% of all the world's freshwater



**Freshwater is SCARCE!**



**The Global Water Cycle**



**(2) Cycling:**

Pathways:

*Precipitation, Evaporation, Vapor transport, Runoff*

Residence Times:

(A) Ocean  $R_T = (\text{total in ocean}) / (\text{evaporation})$   
 $= (1,350 \times 10^6 \text{ km}^3) / (0.425 \times 10^6 \text{ km}^3/\text{yr})$   
 $= 3,176 \text{ years}$

(B) Calculate the atmospheric residence time = ?

**(3) Controls:**

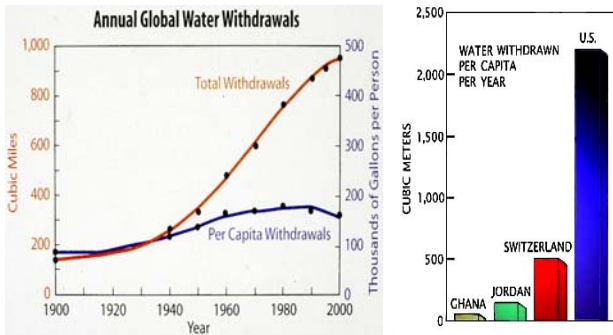
(A) **Human Consumption**

(B) **Temperature**

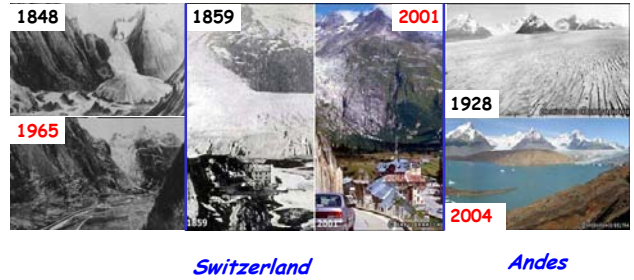
1. **Glacier melting**
2. **Sea level rise**
3. **Changes in deep-water formation**

(C) **Land-use changes**

**A. Human Consumption of Freshwater**  
*Local problems, soon to become regional problems*



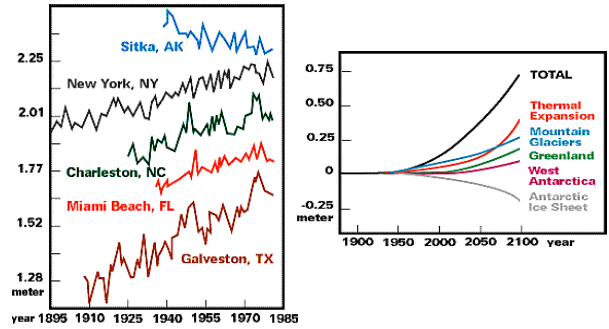
**B. Increasing Temperature is Melting Glaciers**



*Mountain and coastal glaciers in Alaska have melted substantially in the last 50 years*



*Increasing temperatures are raising the mean sea level*

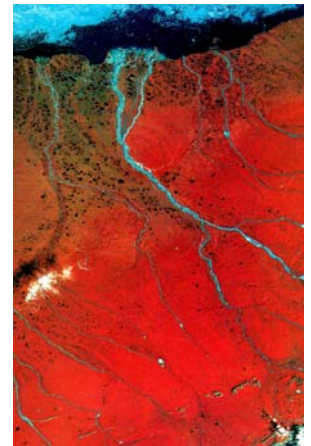


*A rise in sea level of ~4.7 m would flood almost half of southern Florida*

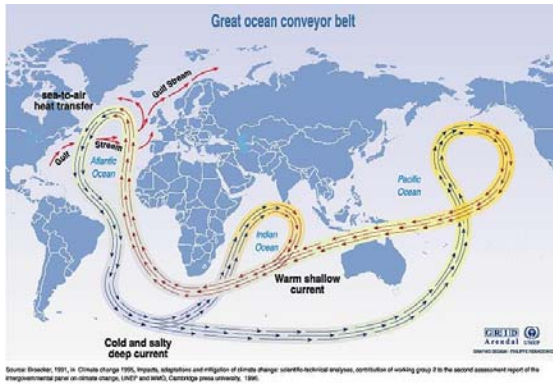


The flow of freshwater in rivers to the Arctic Ocean will likely increase as the temperature warms and glaciers melt.

This could place a "cap" on the sea and prevent deep-water from forming.



**Increased freshwater input to the Arctic Ocean may prevent "deep-water formation"**



**Interactions in the Hydrological Cycle**  
*Low water levels on Lake Michigan in 2000*

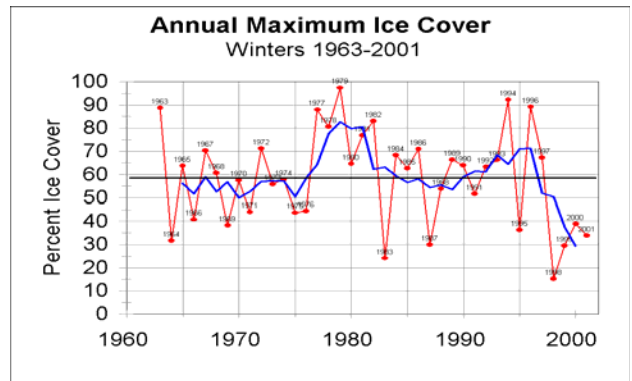


**Why were lake levels so low in 2000?**

*Precipitation was normal for that year!*



**Reduced ice cover increased the amount of time for evaporation to lower the lake levels.**



**The Global Nitrogen Cycle**

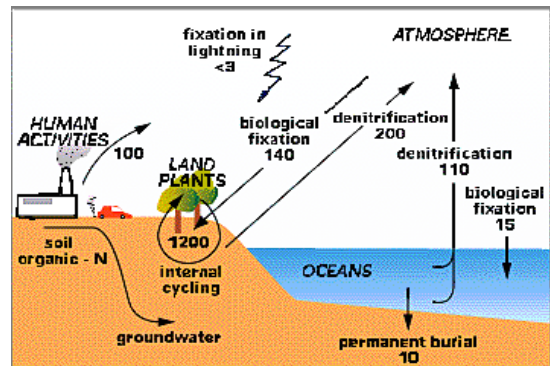
*Accounting, Cycling, and Controls*

**(1) Accounting:**

Location	Amount (10 <sup>15</sup> g)
Rocks & Sediments (unavailable)	190,400,120
Atmosphere	3,900,000
Ocean	23,348
Soils	460
Land Plants	14
Land Animals	0.2

*In the atmosphere,* N<sub>2</sub> = 3,900,000  
 N<sub>2</sub>O = 1.4  
 NO<sub>x</sub> = 0.0006

**The Global Nitrogen Cycle – Pathways and Fluxes**

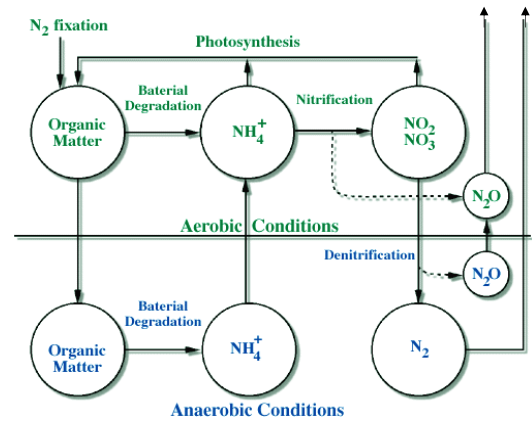


*Fluxes in 10<sup>12</sup> g/yr*

(2) Cycling

Pathways and Reactions:

- $N_2 \rightarrow$  Organic N                    “N-fixation”
- Organic N  $\rightarrow$   $NH_4^+$                 “Mineralization”
- $NH_4^+ \rightarrow$   $NO_3^- + NO + N_2O$       “Nitrification”
- $NO_3^- \rightarrow$   $N_2 + N_2O$                 “Denitrification”
- $NO_3^-$  or  $NH_4^+ \rightarrow$  Organic N    “Plant Assimilation”



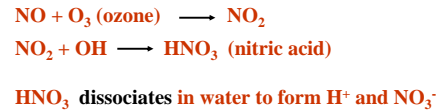
(2) Cycling

Fluxes and Residence Times:

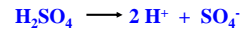
- $R_T$  of  $N_2$  in the atmosphere =  
 $= (\text{total in atm, } 10^{15}\text{g}) / (\text{output, } 10^{15}\text{g/yr})$   
 $= (3,900,000) / (0.158)$   
 $= 24.68$  Million years
- $R_T$  of  $NO_x$  ( $NO + NO_2$ ) in the atmosphere =  
 $(0.6) / (60) = 0.01$  year = 3.6 days

(3) Controls -- examine the case of Acid Rain

(A)  $NO_x$  and Acid Rain

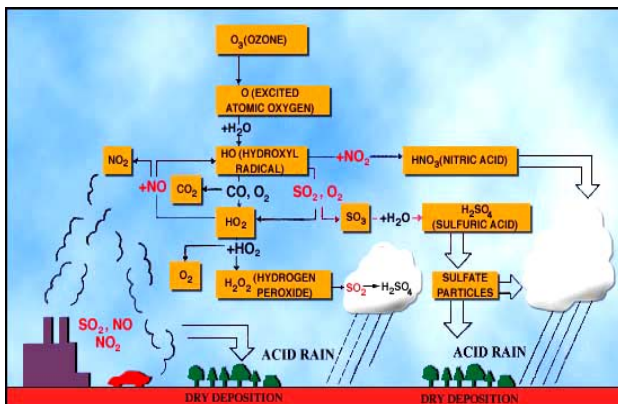


(B) Sulfuric acid formation

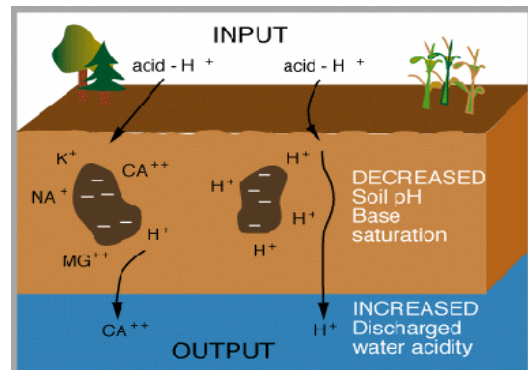


- The  $H^+$  product in both reactions provides the “acidity”
- Acid Rain is caused by a combination of element cycles

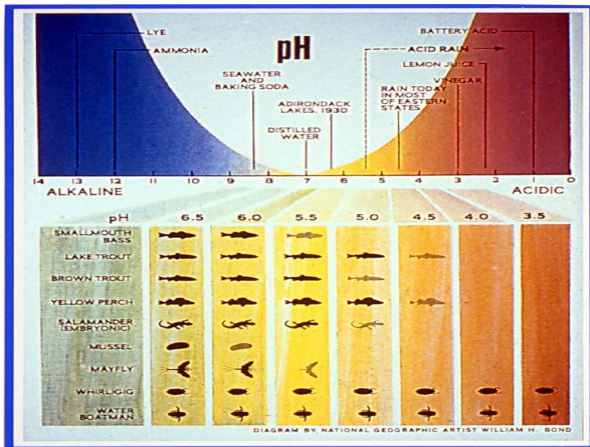
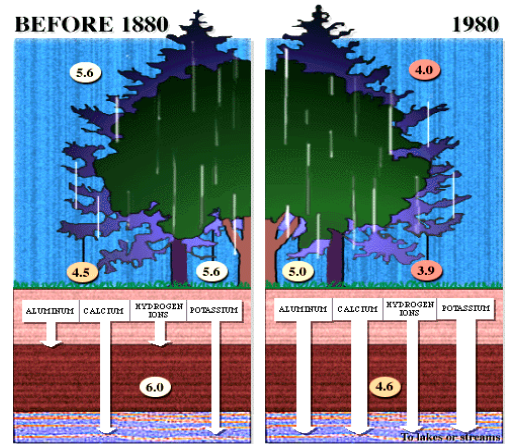
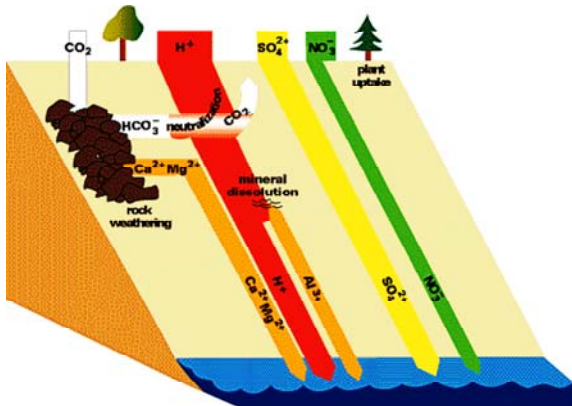
Atmospheric chemical reactions that produce acid rain



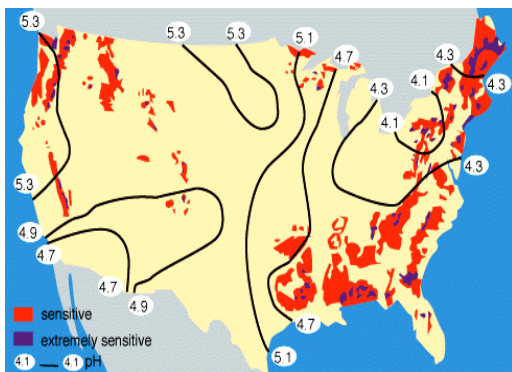
Chemical reactions with  $H^+$  in the soil lead to loss of buffering capacity



H<sup>+</sup> input increases the output of cations like Aluminum



Many areas of the U.S. are sensitive to acid rain



### Summary

- The hydrological cycle is influenced or controlled by temperature, land-use changes, and human consumption.
- Acid Rain is an important consequence of the nitrogen and sulfur cycles interacting. Acid rain is produced by the interactions of these and other elements in the atmosphere, and the impacts of acid rain are controlled by other element cycles on land and in the water.
- The main take-home message for today's lecture is:

***"ELEMENT CYCLES INTERACT,  
and they cannot be studied in isolation"***