The Airshed: Connecting Air, Land and Water

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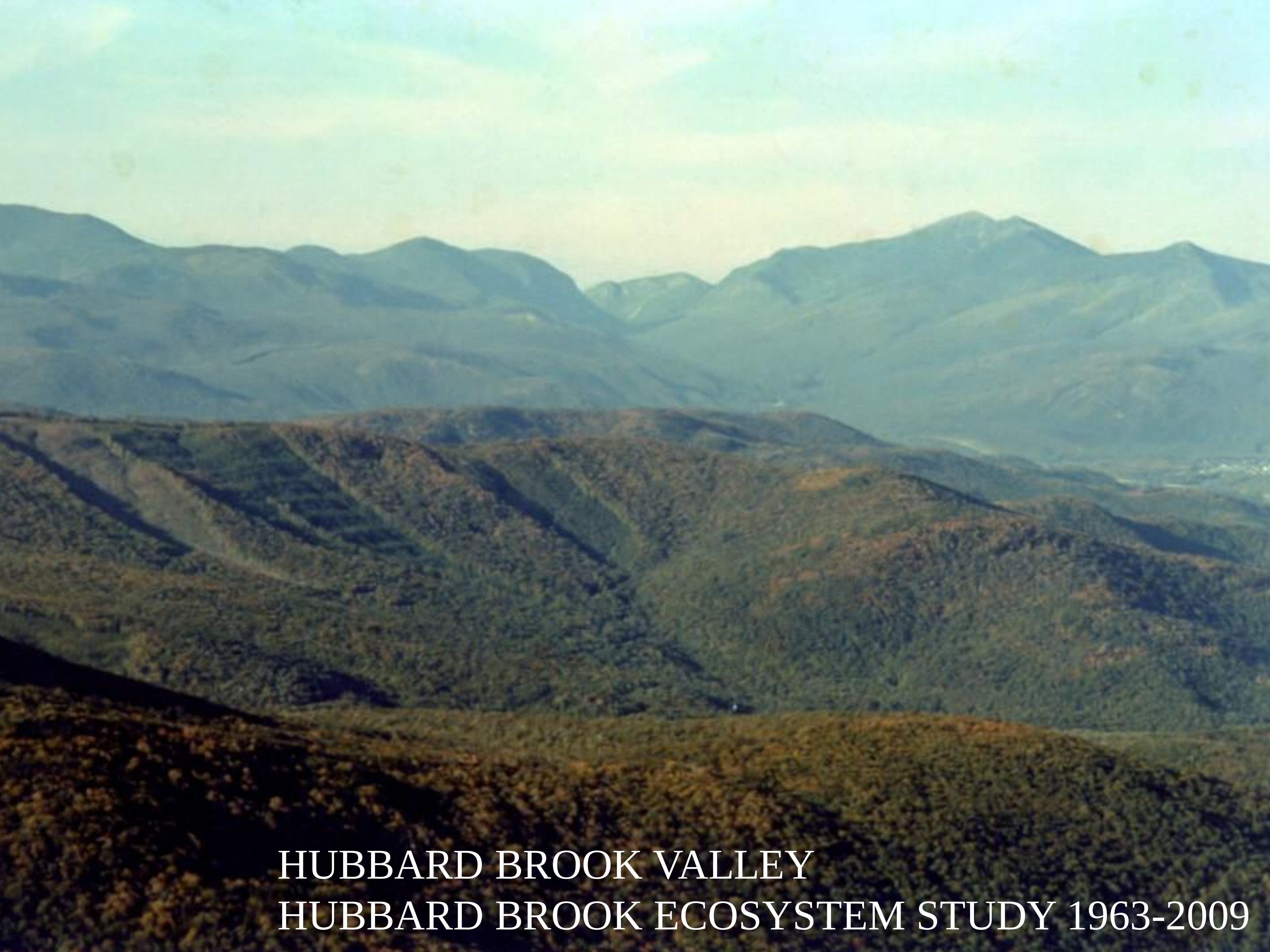
(Hubbard Brook Ecosystem Study)

Airshed Inputs

- Hydrology (precipitation)
- Biogeochemical Flux
- Wind
- Solar Radiation

Airshed Outputs

- Cold Air Drainage (e.g.Pypker et al. 2007)
- Hydrology (evapotranspiration)
- Outgoing radiation


HUBBARD BROOK VALLEY
HUBBARD BROOK ECOSYSTEM STUDY 1963-2009

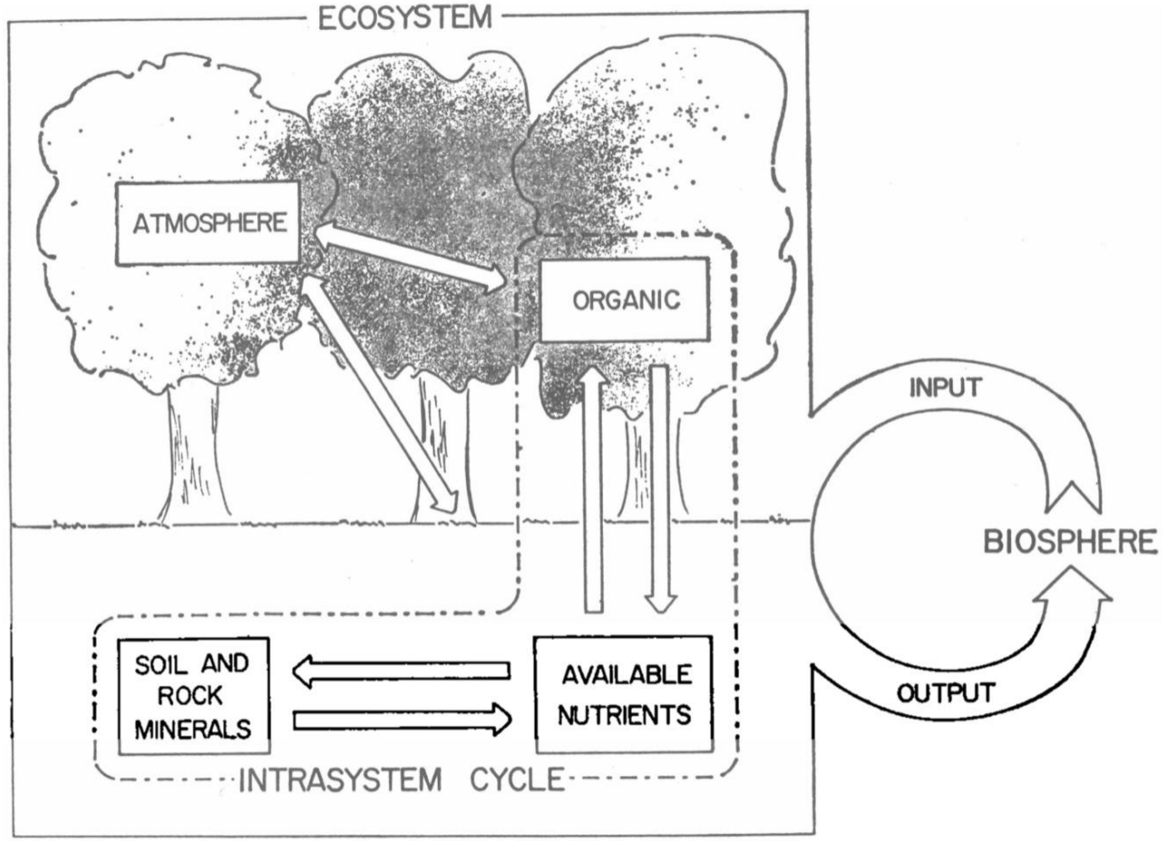
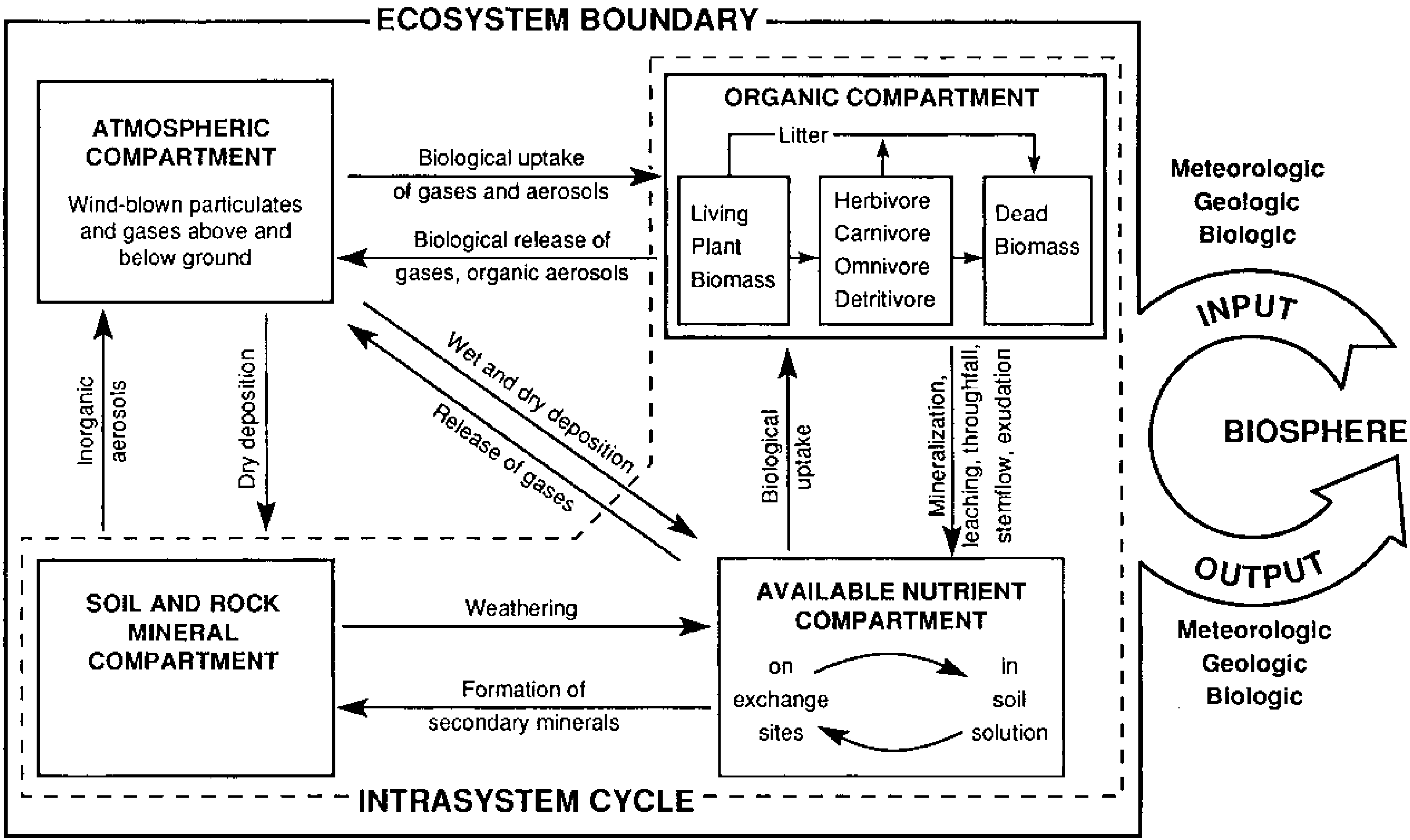


Fig. 1. Nutrient relationships of a terrestrial ecosystem, showing sites of accumulation and major pathways. Input and output may be composed of geologic, meteorologic, and biologic components, as described in the text.

Bormann and Likens 1967. Science

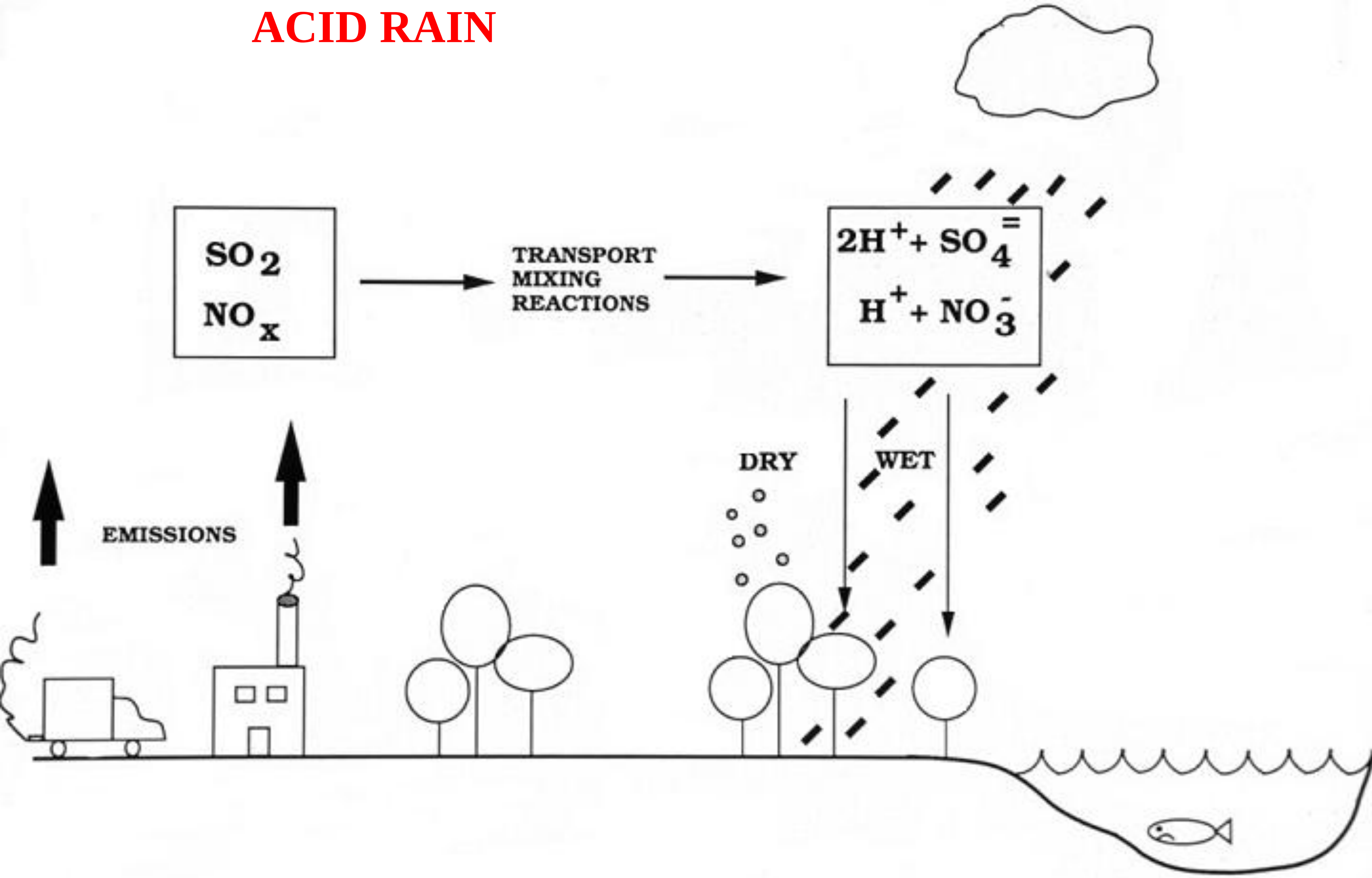

ECOSYSTEM BOUNDARY
ATMOSPHERIC COMPARTMENT
Wind-blown particulates and gases above and below ground
Biological uptake of gases and aerosols
Biological release of gases, organic aerosols
ORGANIC COMPARTMENT
Litter
Living Plant Biomass
Herbivore Carnivore Omnivore Detritivore
Dead Biomass
Meteorologic
Geologic
Biologic
INPUT
BIOSPHERE
OUTPUT
Meteorologic
Geologic
Biologic
Inorganic aerosols
Dry deposition
Wet and dry deposition
Release of gases
Biological uptake
Mineralization, leaching, throughfall, stemflow, exudation
SOIL AND ROCK MINERAL COMPARTMENT
Weathering
Formation of secondary minerals
AVAILABLE NUTRIENT COMPARTMENT
on exchange sites
in soil solution
INTRASYSTEM CYCLE

Likens 1992

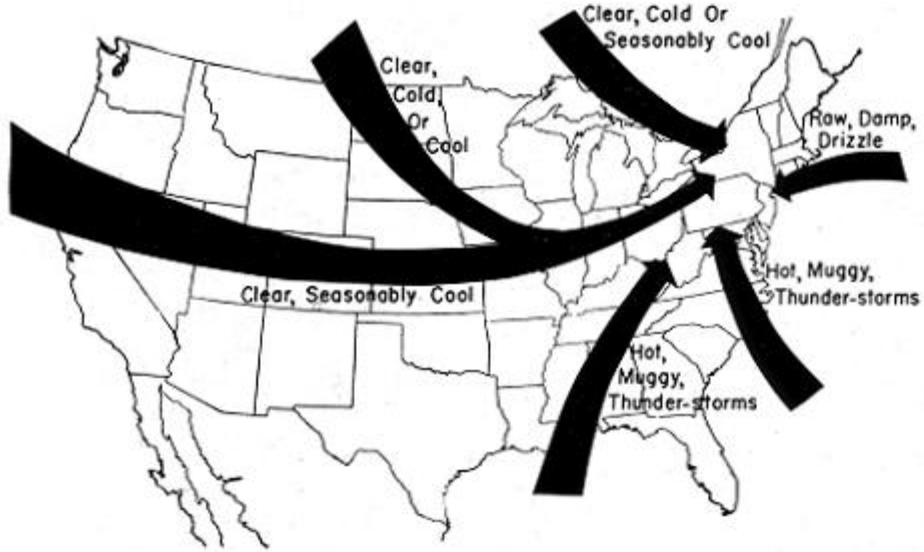
PRECIPITATION COLLECTORS


11
R
R

ACID RAIN



SO_2
NO_x
TRANSPORT
MIXING
REACTIONS
$2H^+ + SO_4^=$
$H^+ + NO_3^-$
DRY
WET
EMISSIONS



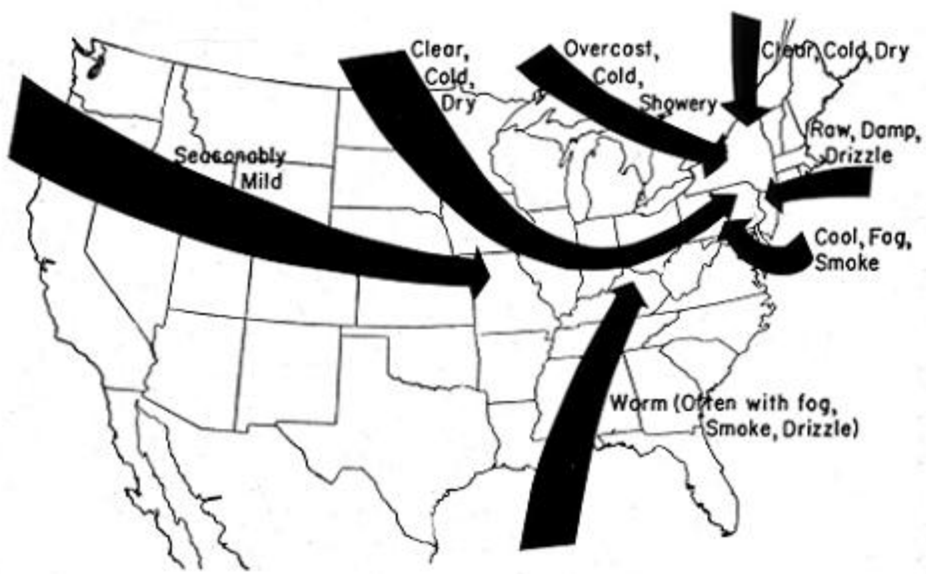
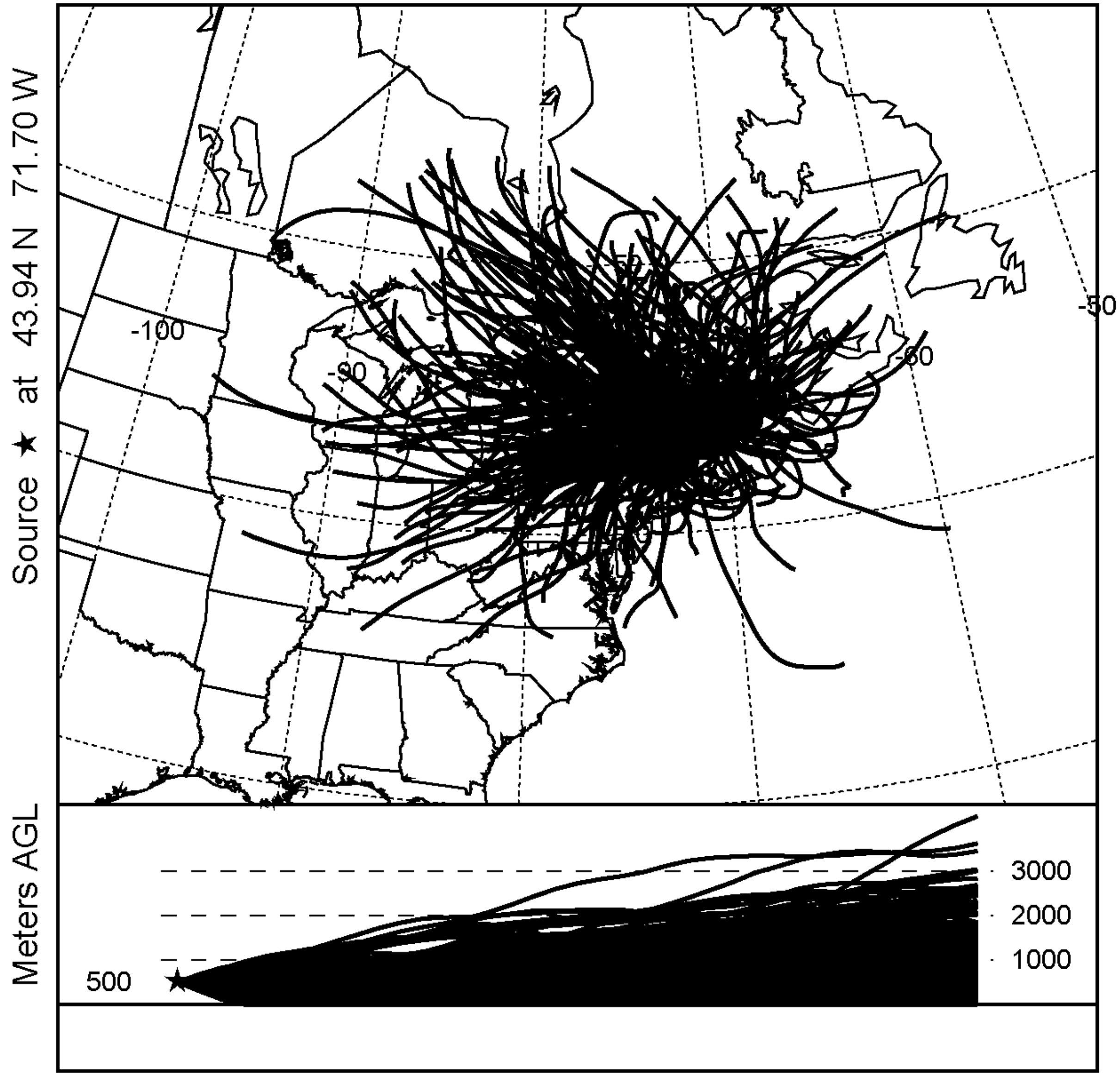
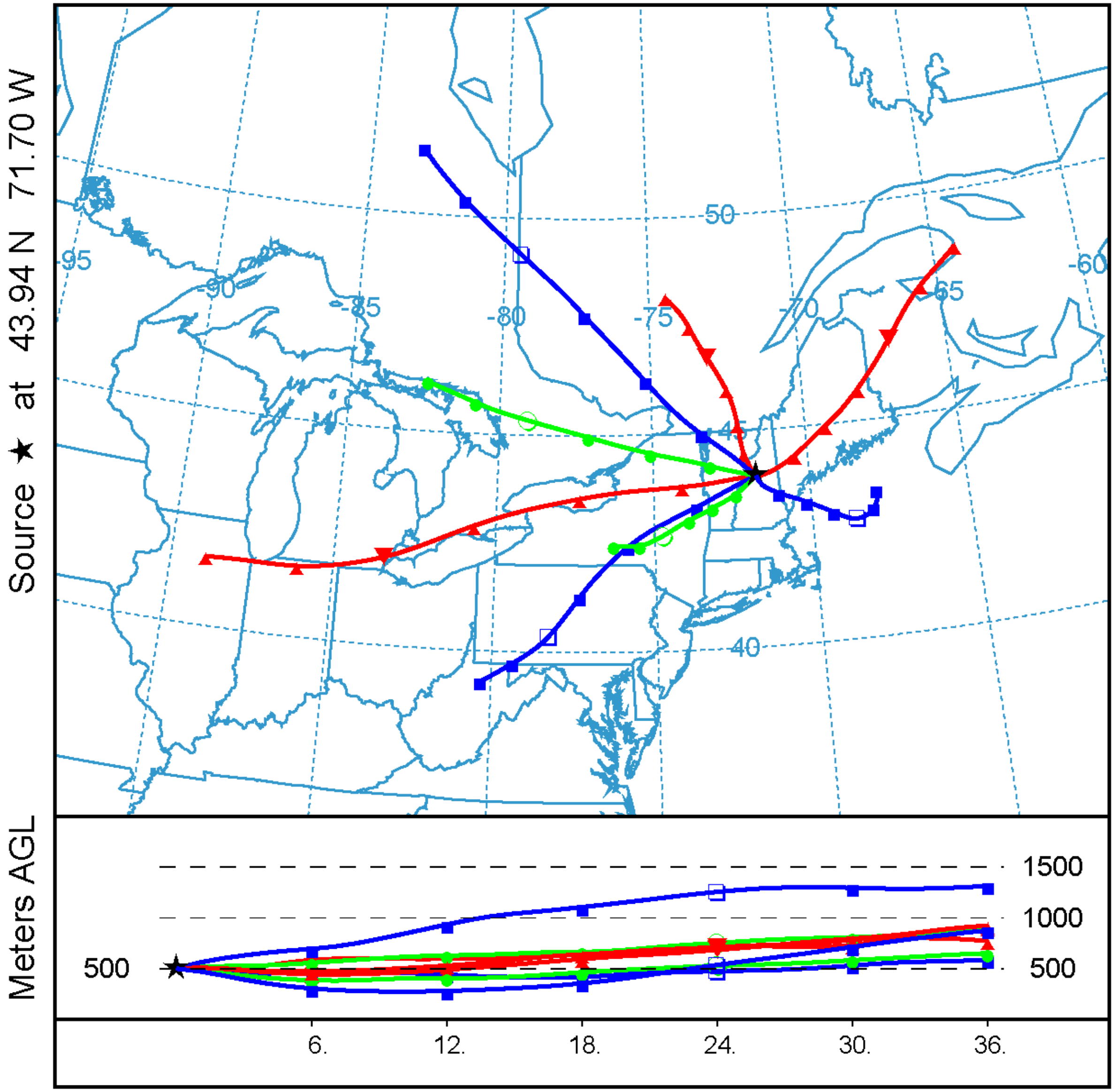


Figure 2. *Top*: Principal paths of air masses entering New York State during April–September period. *Bottom*: Principal paths of air masses entering New York State during October–March period.

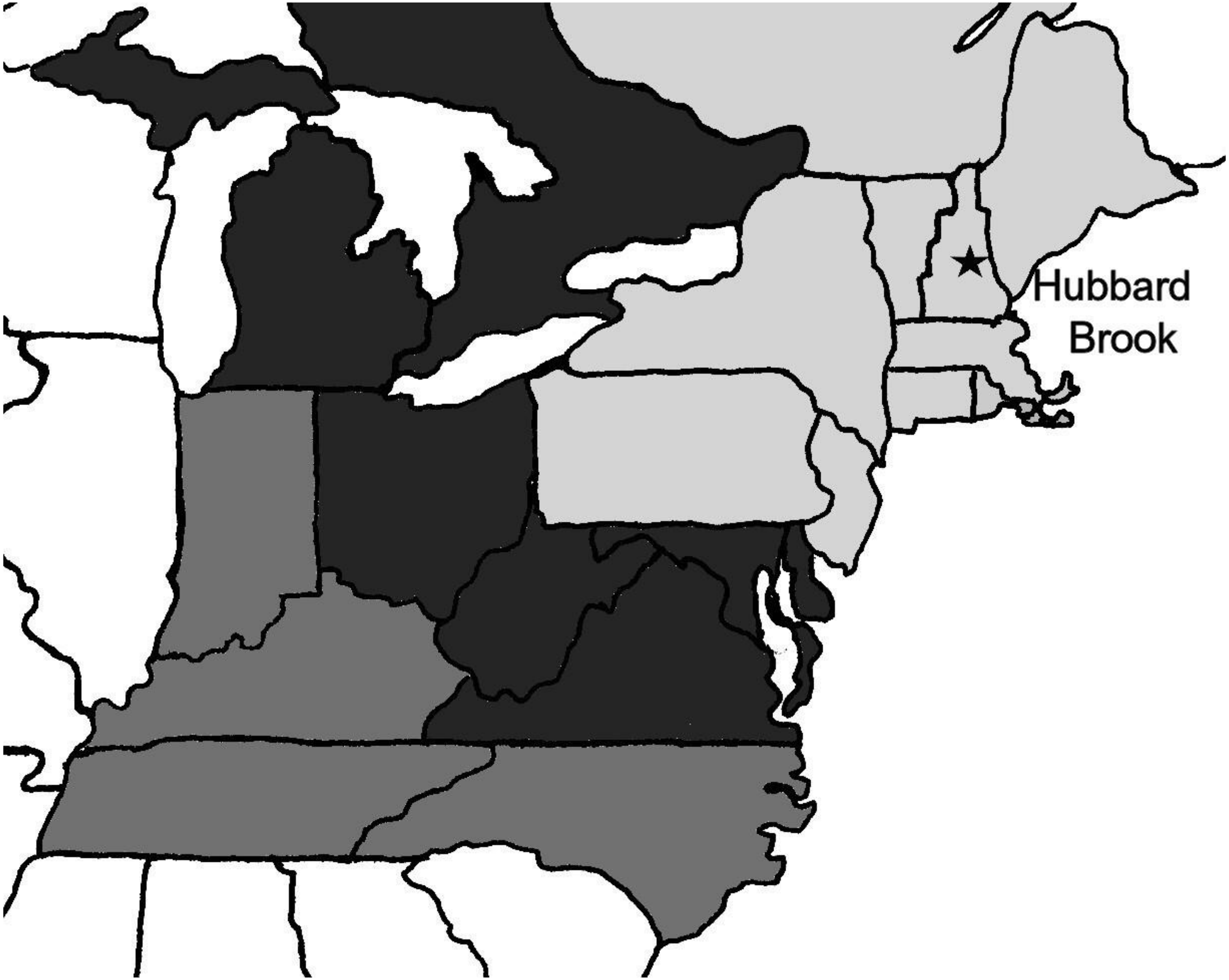


Hysplit-4 (Draxler and Hess, 1998) model 36-hr back trajectories for Hubbard Brook Experimental Forest; 500 m start height for year 2000

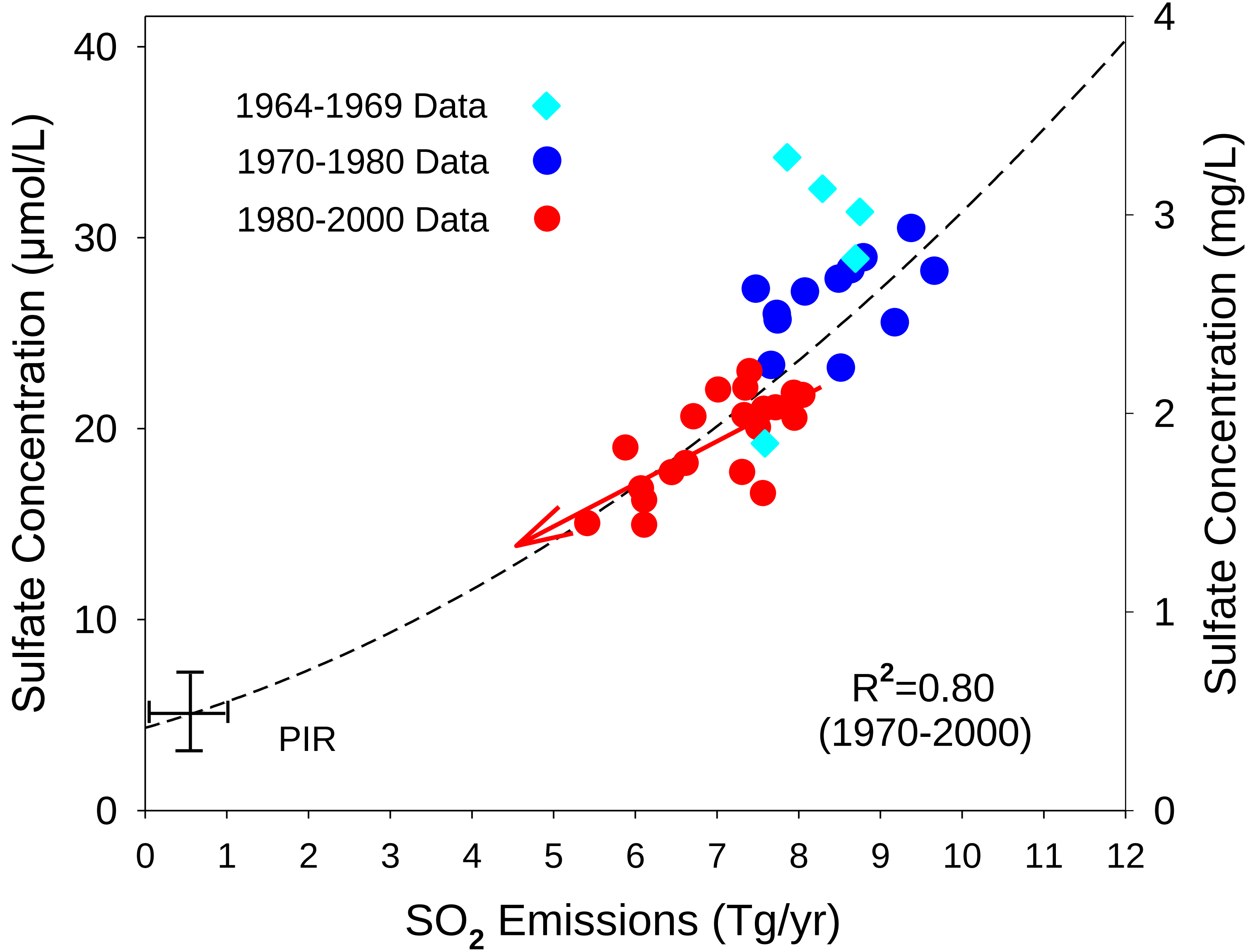
THE SOURCE-AREA PROBLEM



Cluster analysis (Stunder ,1996) : 500m start height., 36-hr back trajectories
for year 2000 at Hubbard Brook Experimental Forest

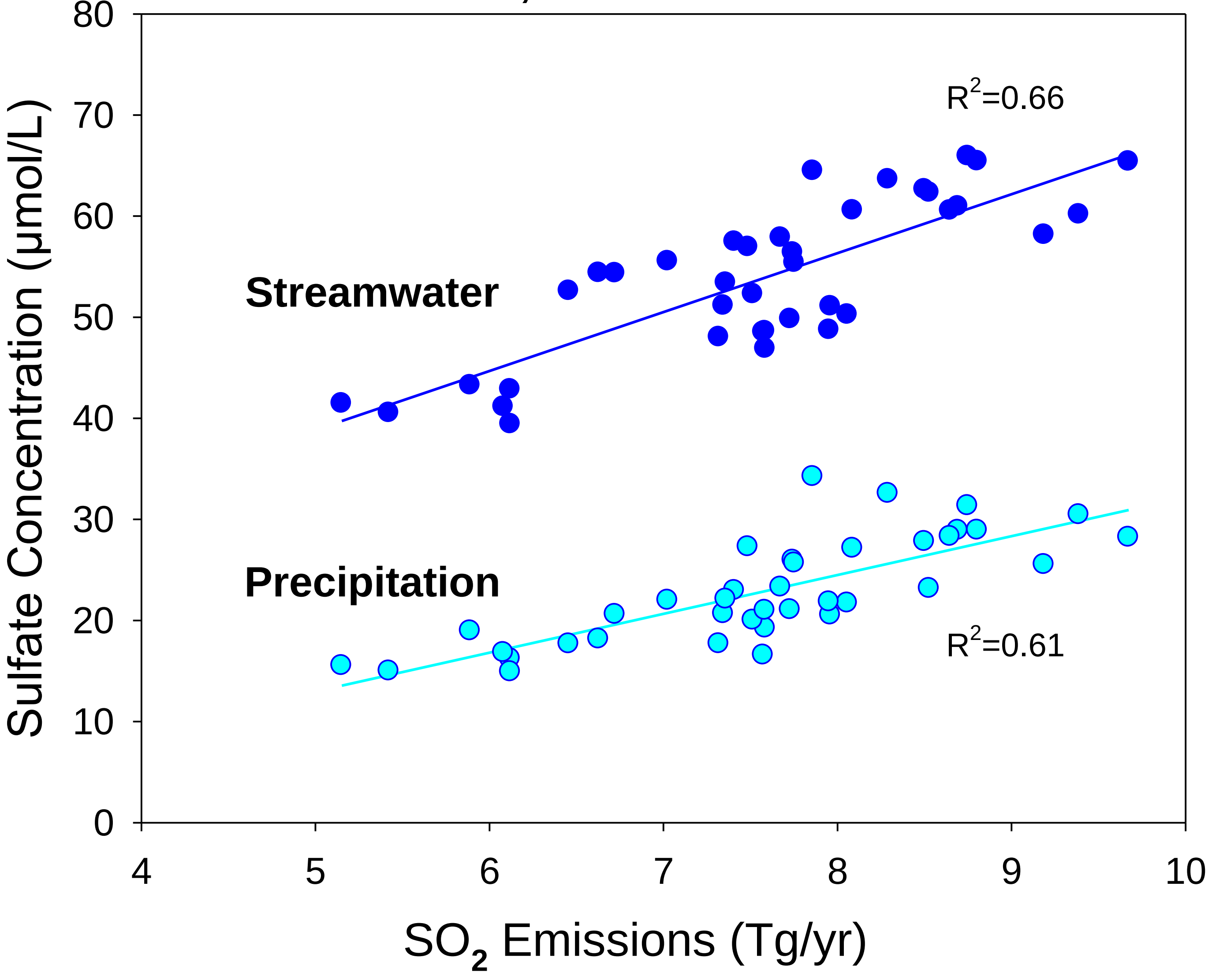


States representing source areas for Hubbard Brook Experimental Forest precipitation, based on 12-hr, 24-hr and 36-hr back trajectories (from Likens et al., 2005)



HBEF 24-hr Source Area (Likens et al. 2005 JEM)

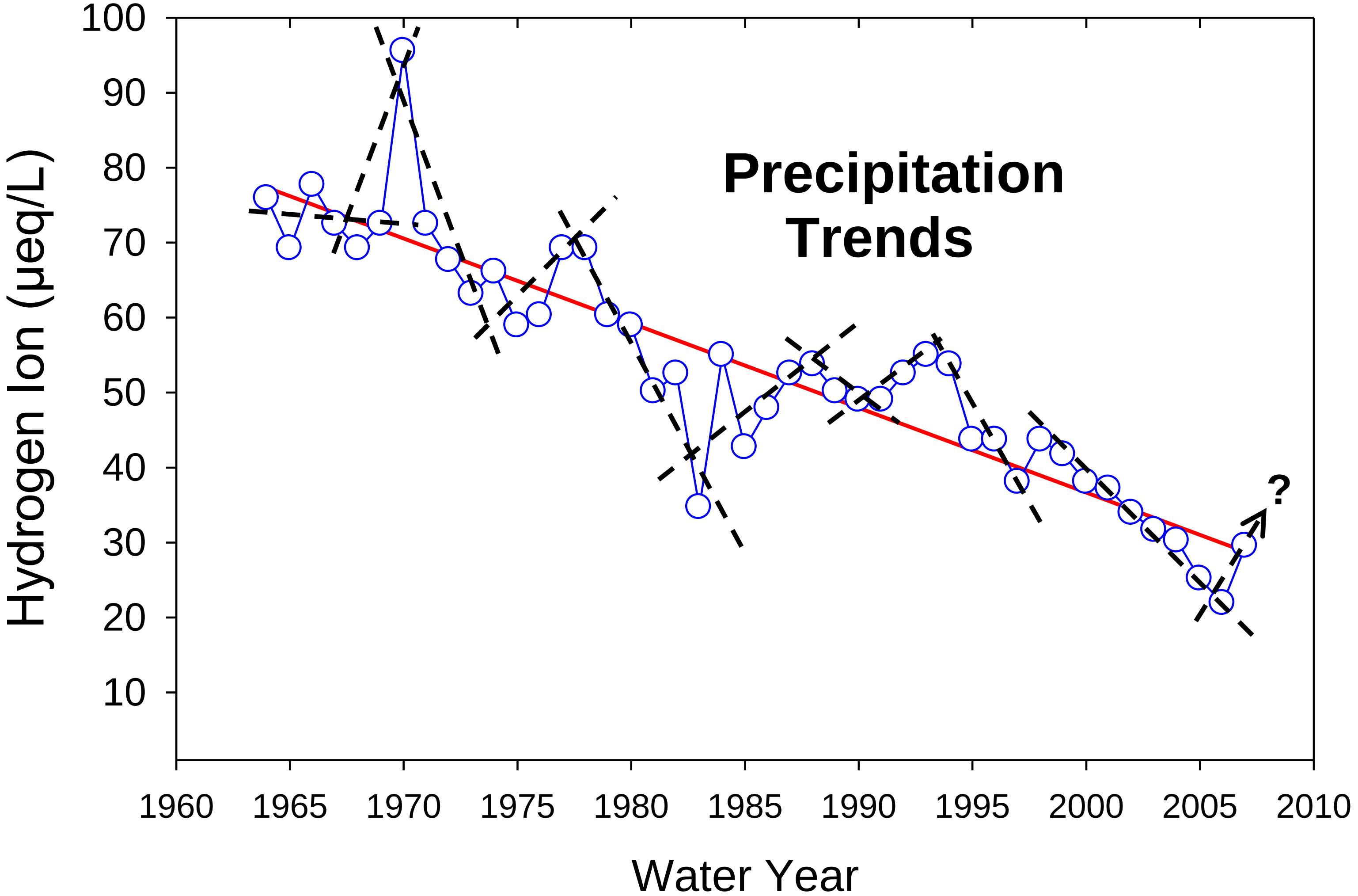
CONNECTING AIR, LAND AND WATER



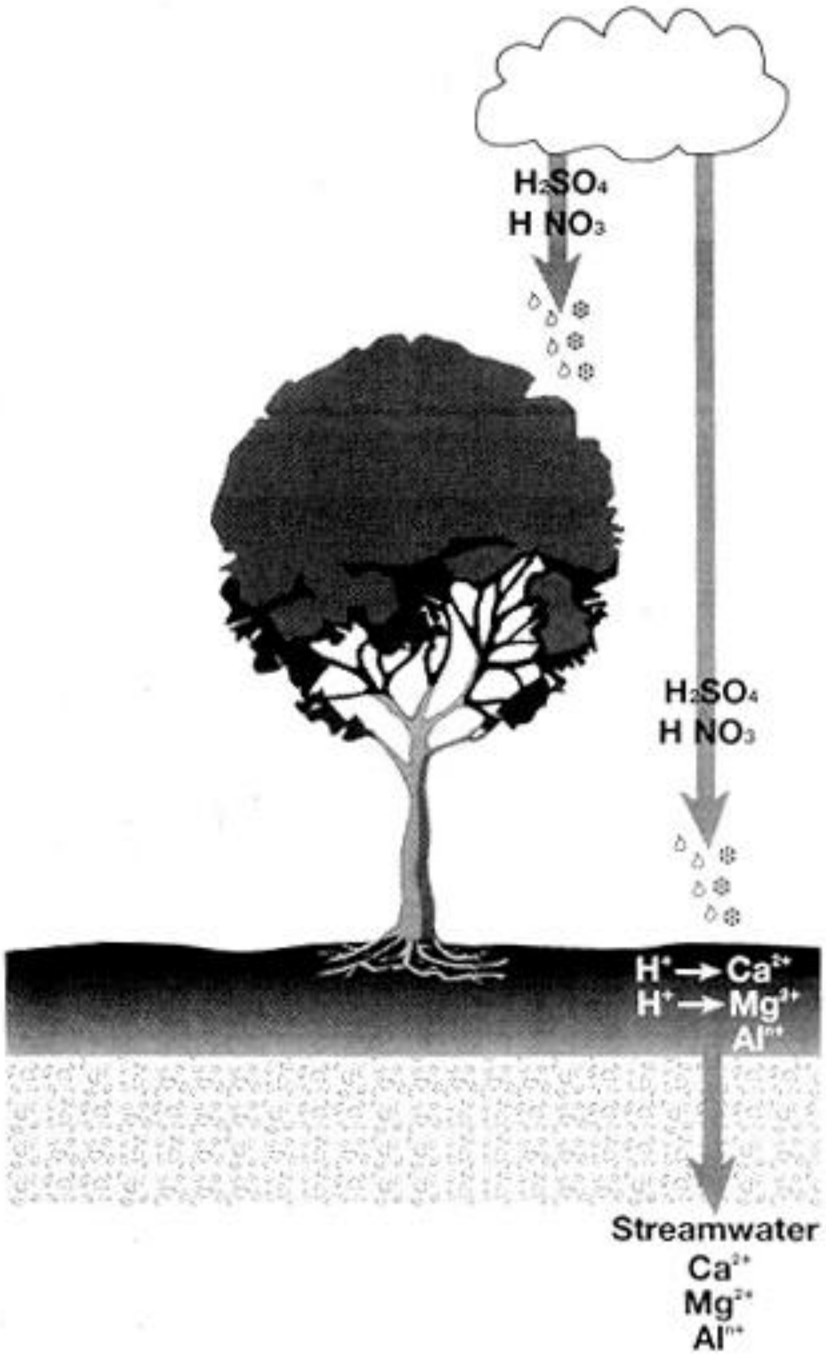
HBEF 24-hr Source Area (Likens et al. 2005 JEM)

We also have determined that a unit decrease in NO_x emissions would result in a 75-95% decrease in NO_3^- concentration in precipitation

(Butler et al. 2003)



Likens and Buso 2009

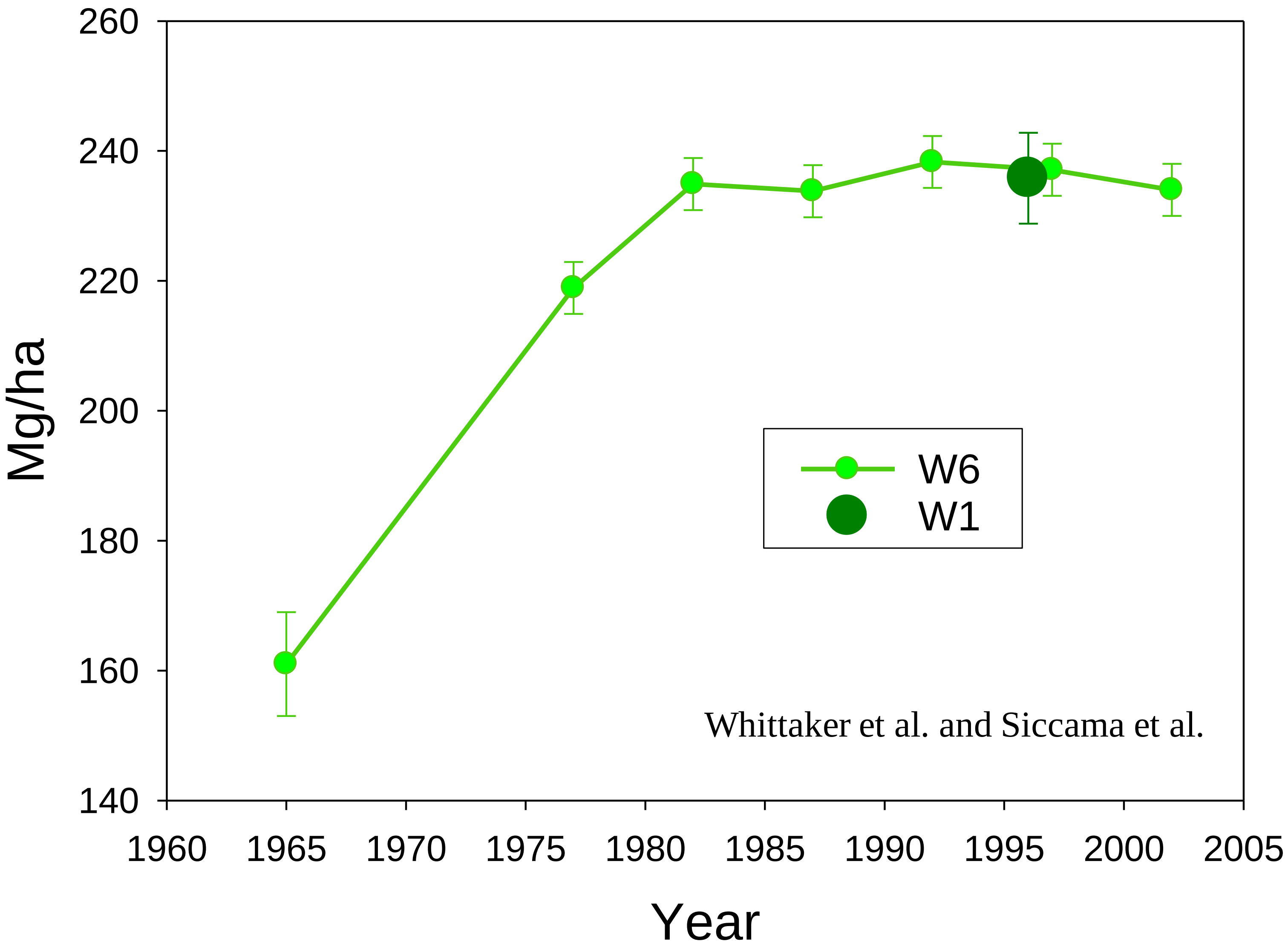


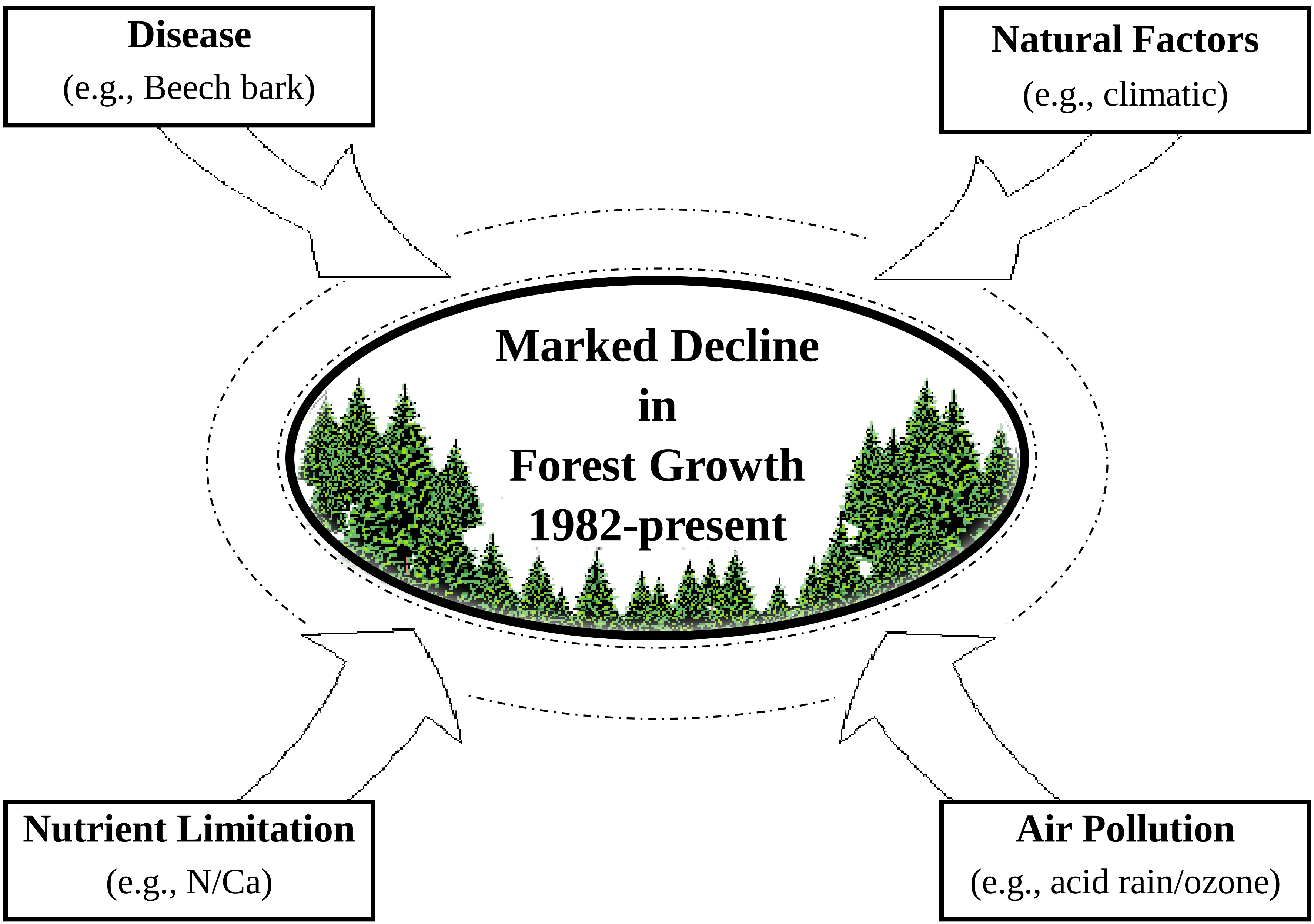
H_2SO_4
$H\ NO_3$
H_2SO_4
$H\ NO_3$
$H^+ \rightarrow Ca^{2+}$
$H^+ \rightarrow Mg^{2+}$
Al^{n+}
Streamwater
Ca^{2+}
Mg^{2+}
Al^{n+}

About 842 Kg of calcium/ha depleted from soil pools during 1940 to 1995.

(*Likens et al. Science 1996*)

Live, above-ground biomass: total of all size classes




Disease
(e.g., Beech bark)
Natural Factors
(e.g., climatic)
Marked Decline
in
Forest Growth
1982-present
Nutrient Limitation
(e.g., N/Ca)
Air Pollution
(e.g., acid rain/ozone)


WOLLASTONITE
ADDITION ($CaSiO_3$)

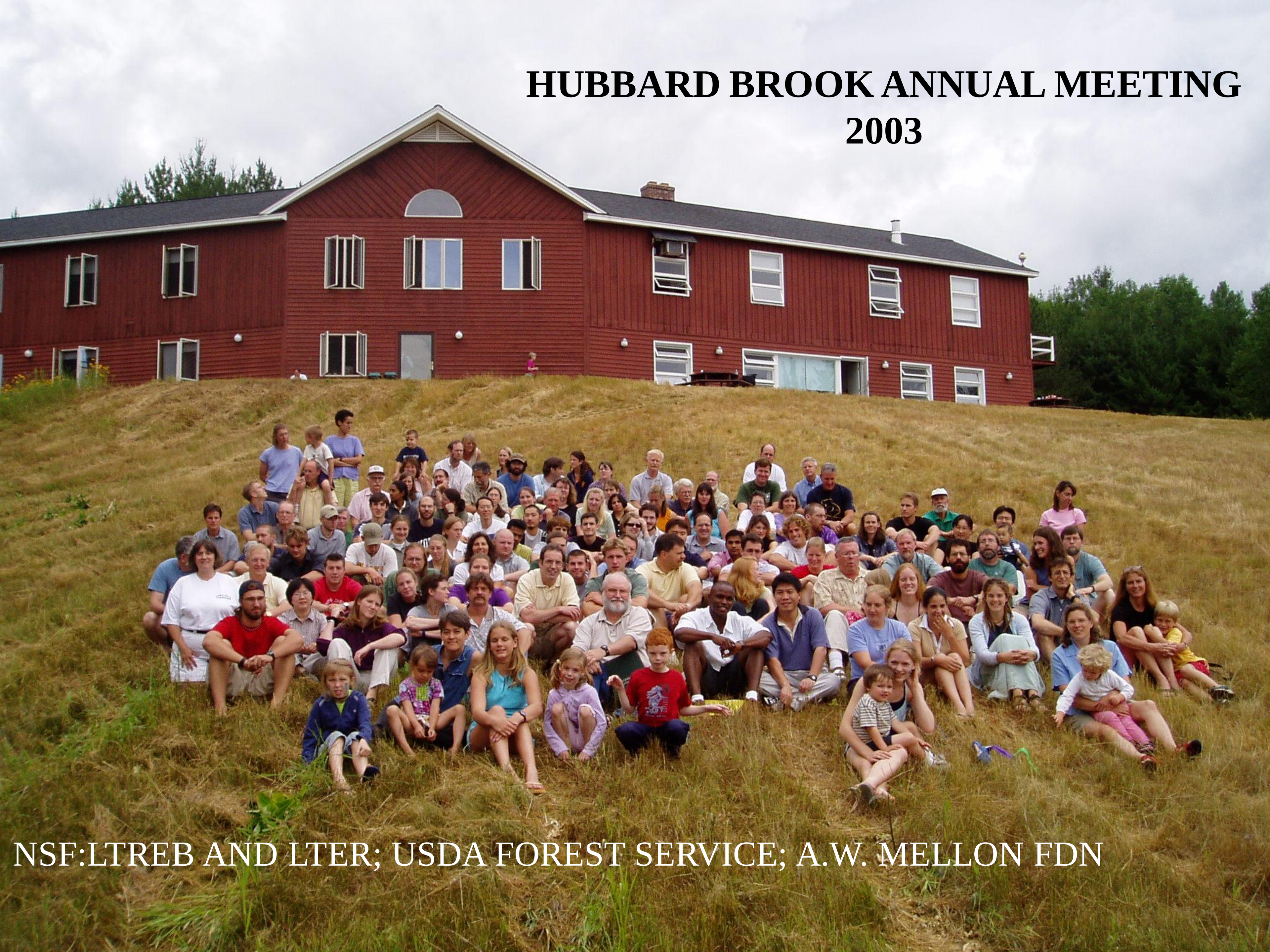
CONNECTIVITY

So, coal mined in eastern Kentucky, burned in a power plant in Detroit, releasing SO_2 to the atmosphere, forming acid rain, leaching base cations from soil in New Hampshire, causing the forest to stop growing, releasing CO_2 to the atmosphere, contributing to global warming/climate change, which in turn, impacts the forest!!

Another Example: Impact of Climate Change

- Fires and Floods in Australia – Feb 2009

HUBBARD BROOK ANNUAL MEETING
2003

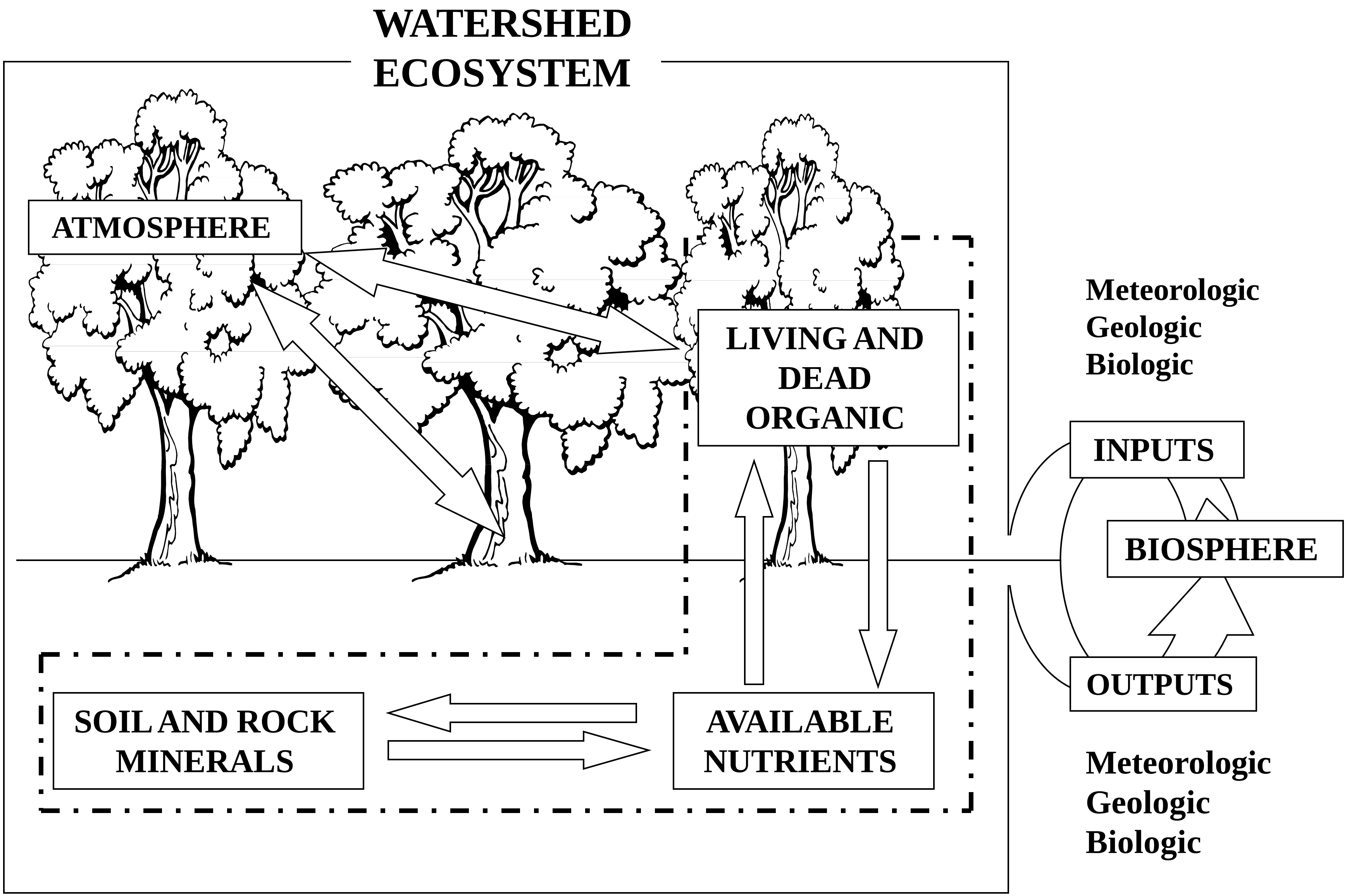


NSF:LTREB AND LTER; USDA FOREST SERVICE; A.W. MELLON FDN

Slide comments

- Slide 1&2 is an example of using back trajectories to estimate a source area for emissions impacting a location, in this case Hubbard Brook. The first slide (resembling a plate of spaghetti) represents all the daily back trajectories for the year 2000. However it is hard to see the "forest for the trees" here. The next slide uses cluster analysis to group together similar back trajectories. It is an iterative process where trajectories continue to be grouped until a prescribed number of final "averaged" back trajectories remain (in this case 8 final36-hr trajectories). Each mark on a back trajectory represents 6 hrs. We use this approach to estimate different sized source regions (i.e. based on 12-hr, 24-hr or 36-hr back trajectories).
- We use different heights (usually 500m and 1000m start hts to capture air flows both below the boundary layer (500 m) and near the top of the boundary layer (1000m) .
- Slide 3 is an estimate of source regions for HB based on only days when precipitation occurred (the back trajectories are based on a start time in the middle of a storm on days when at least 2.5 mm of precip fell for the years 1995 &1996 (see Likens , Buso, Butler 2005 for more detail)

NAPAP concluded that forest soils in the U.S. had not been impacted seriously by acid rain (NAPAP 1990).


WATERSHED
ECOSYSTEM
ATMOSPHERE
LIVING AND
DEAD
ORGANIC
SOIL AND ROCK
MINERALS
AVAILABLE
NUTRIENTS
Meteorologic
Geologic
Biologic
INPUTS
BIOSPHERE
OUTPUTS
Meteorologic
Geologic
Biologic