HOW DOES THE ACID GET INTO THE RAIN?

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Haagen-Smit Clean Air Leadership Talks

HAAGEN-SMIT
CLEAN AIR AWARDS

CALIFORNIA AIR RESOURCES BOARD

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SOUND POLICY REQUIRES FIRM SCIENCE

The three legs of firm understanding in environmental science

Laboratory Studies

Field Measurements

Theory

HOW DOES THE ACID GET INTO THE RAIN?

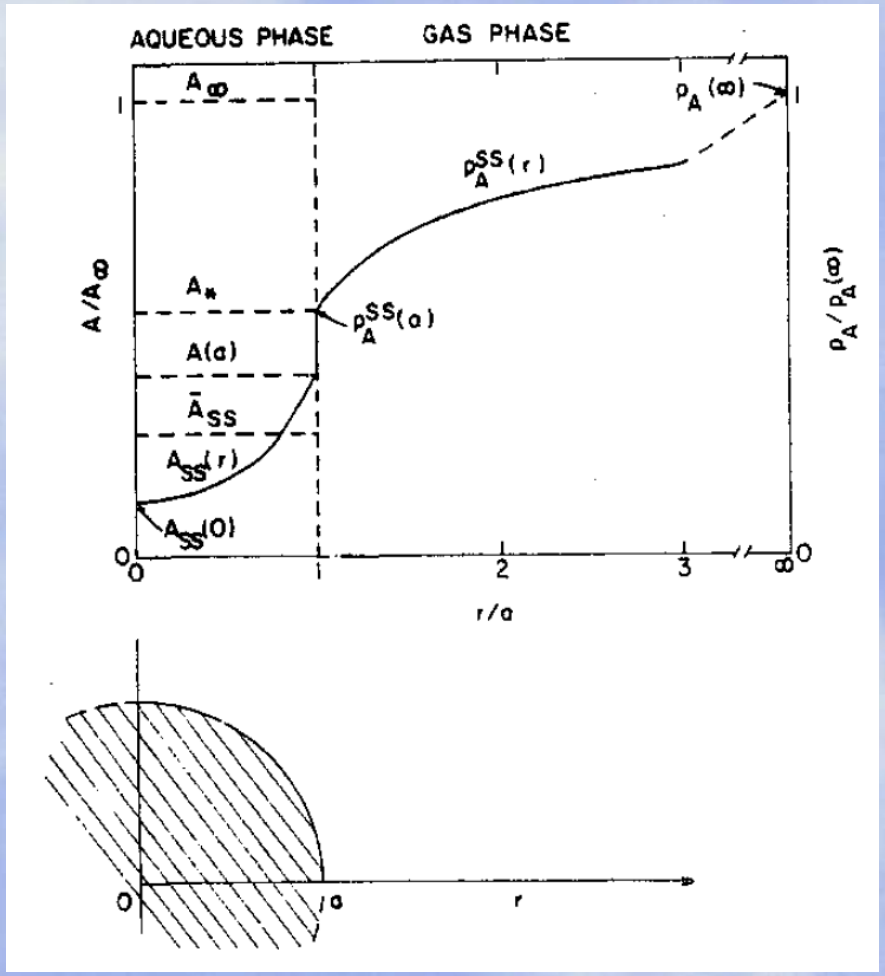
THE CONVENTIONAL WISDOM (circa 1975)

Sulfur dioxide is rapidly oxidized in clear air to sulfuric acid in clear air and subsequently incorporated into clouds and rain.

Nitrogen dioxide reacts rapidly in clouds to form nitric and nitrous acids.

MASS-TRANSPORT LIMITATION TO THE RATE OF REACTION OF GASES IN LIQUID DROPLETS: APPLICATION TO OXIDATION OF SO_2 IN AQUEOUS SOLUTIONS

S. E. SCHWARTZ and J. E. FREIBERG



Fugacity profile of gas diffusing to and reacting within a cloud drop.

Identification of changes in fugacity permits identification of rate-limiting steps in reactive uptake:

- Gas-phase diffusion.
- Interfacial transport controlled by mass-accommodation coefficient.
- Aqueous-phase diffusion.
- Aqueous-phase reaction.

Atmospheric Environment, 1981

ELSEVIER

Haagen-Smit Award 2003

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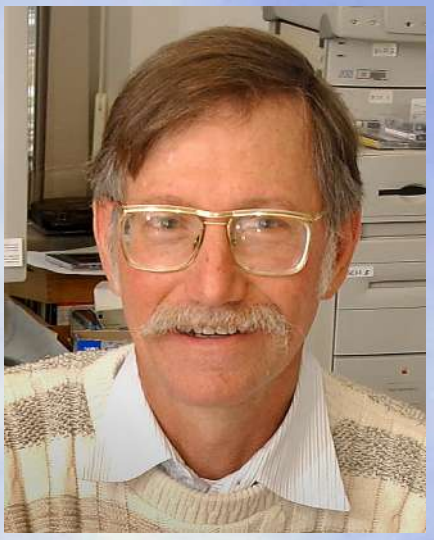


The Executive Editors and the Publisher of *Atmospheric Environment* take great pleasure in announcing the third "Haagen-Smit Award", designed to recognize ***outstanding papers published in Atmospheric Environment***.

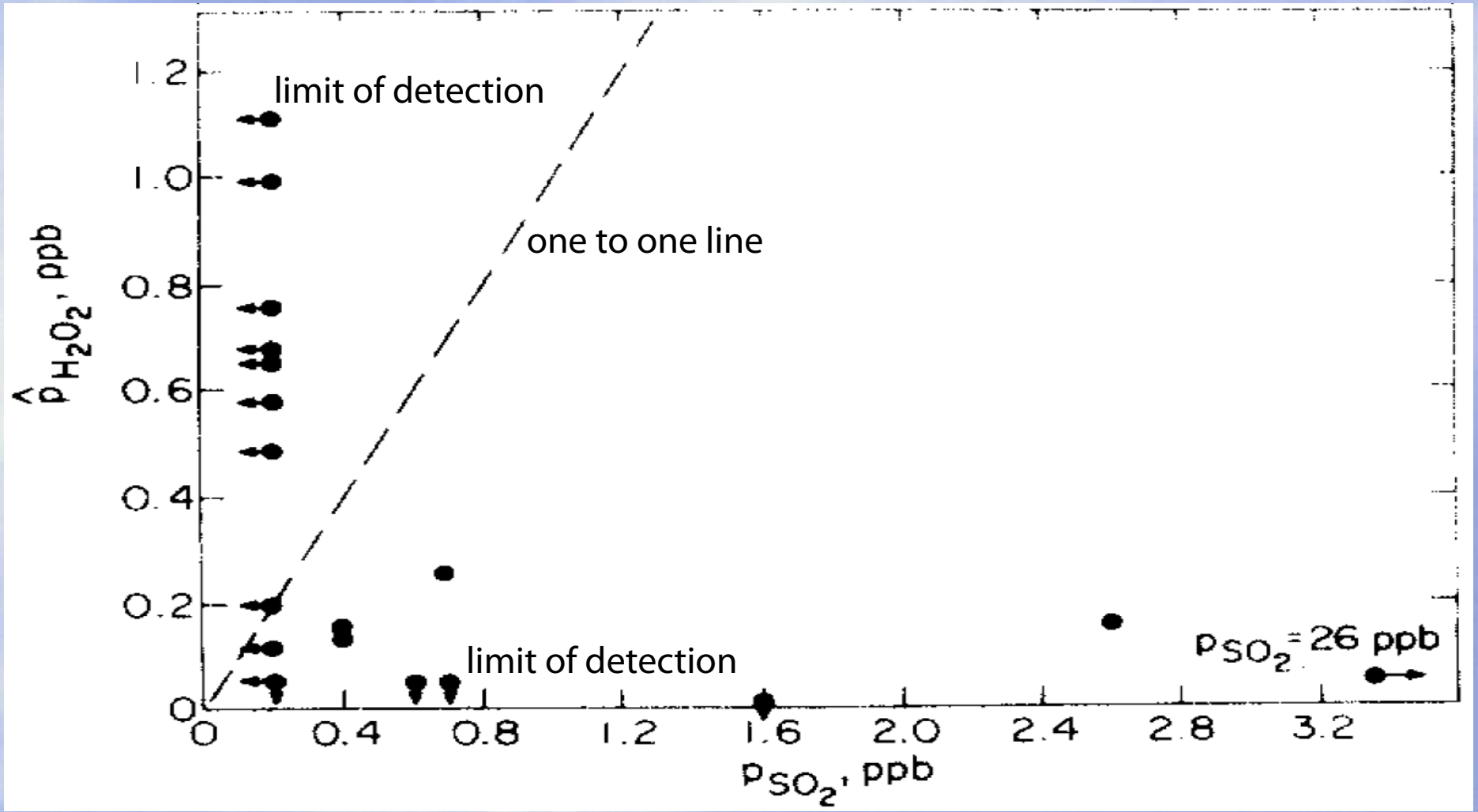
The award is named in honour of Prof. **Arie Jan Haagen-Smit**, a pioneer in the field of air pollution and one of the first editors of the *International Journal of Air Pollution*, a predecessor to *Atmospheric Environment*.

The "Haagen-Smit Award" is given annually to two papers previously published in *Atmospheric Environment* and covering different science areas.

Schwartz, S. E., Freiberg, J. E. 1981. Mass-transport limitation to the rate of reaction of gases in liquid droplets. *Atmospheric Environment* 15, 1129-1144.

MEASUREMENTS OF THE CHEMICAL COMPOSITION OF STRATIFORM CLOUDS

P. H. DAUM, T. J. KELLY, S. E. SCHWARTZ and L. NEWMAN



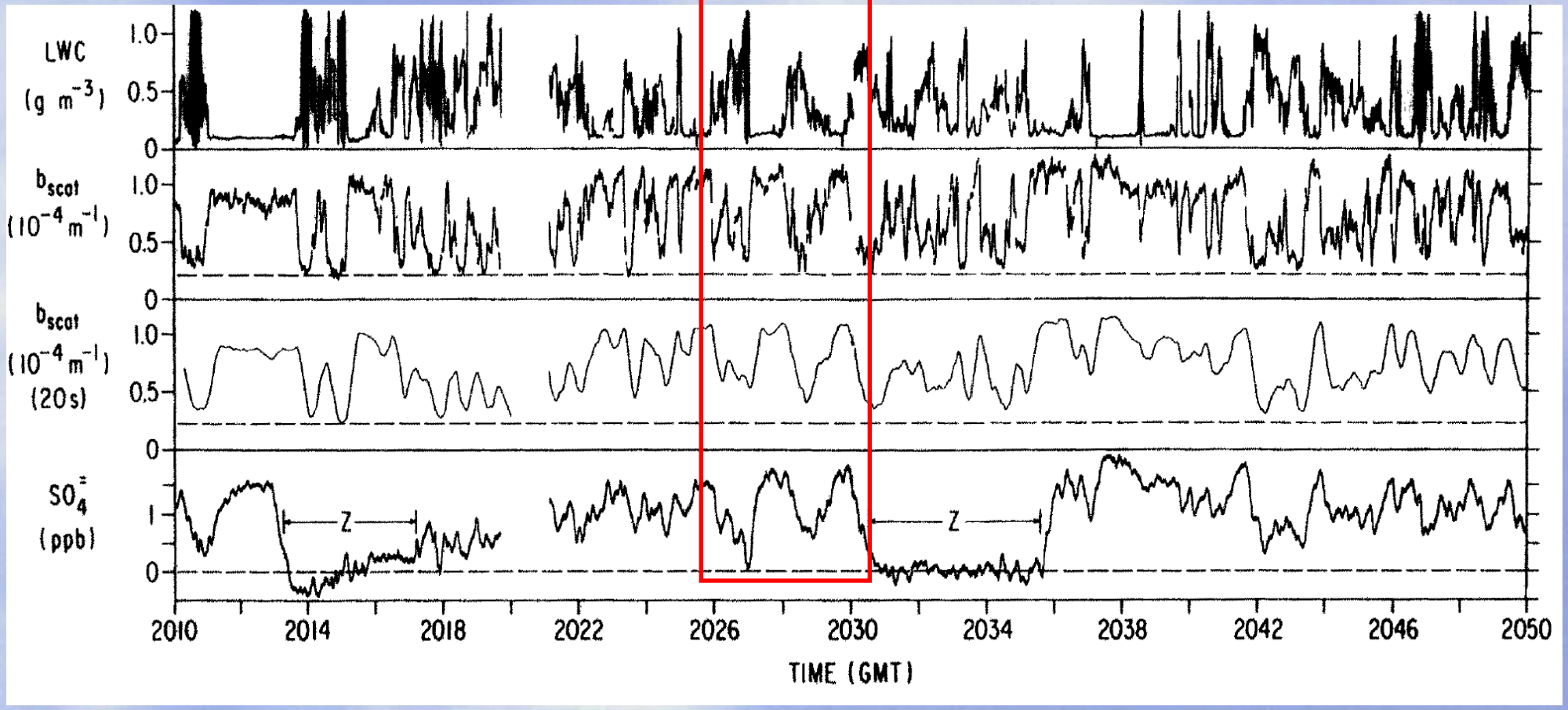
Hydrogen peroxide and sulfur dioxide are mutually exclusive.

Reaction is rapid and one or the other is the limiting reagent.

Atmospheric Environment, 1984

EFFICIENT SCAVENGING OF AEROSOL SULFATE BY LIQUID-WATER CLOUDS*

H. M. TEN BRINK†, S. E. SCHWARTZ and P. H. DAUM



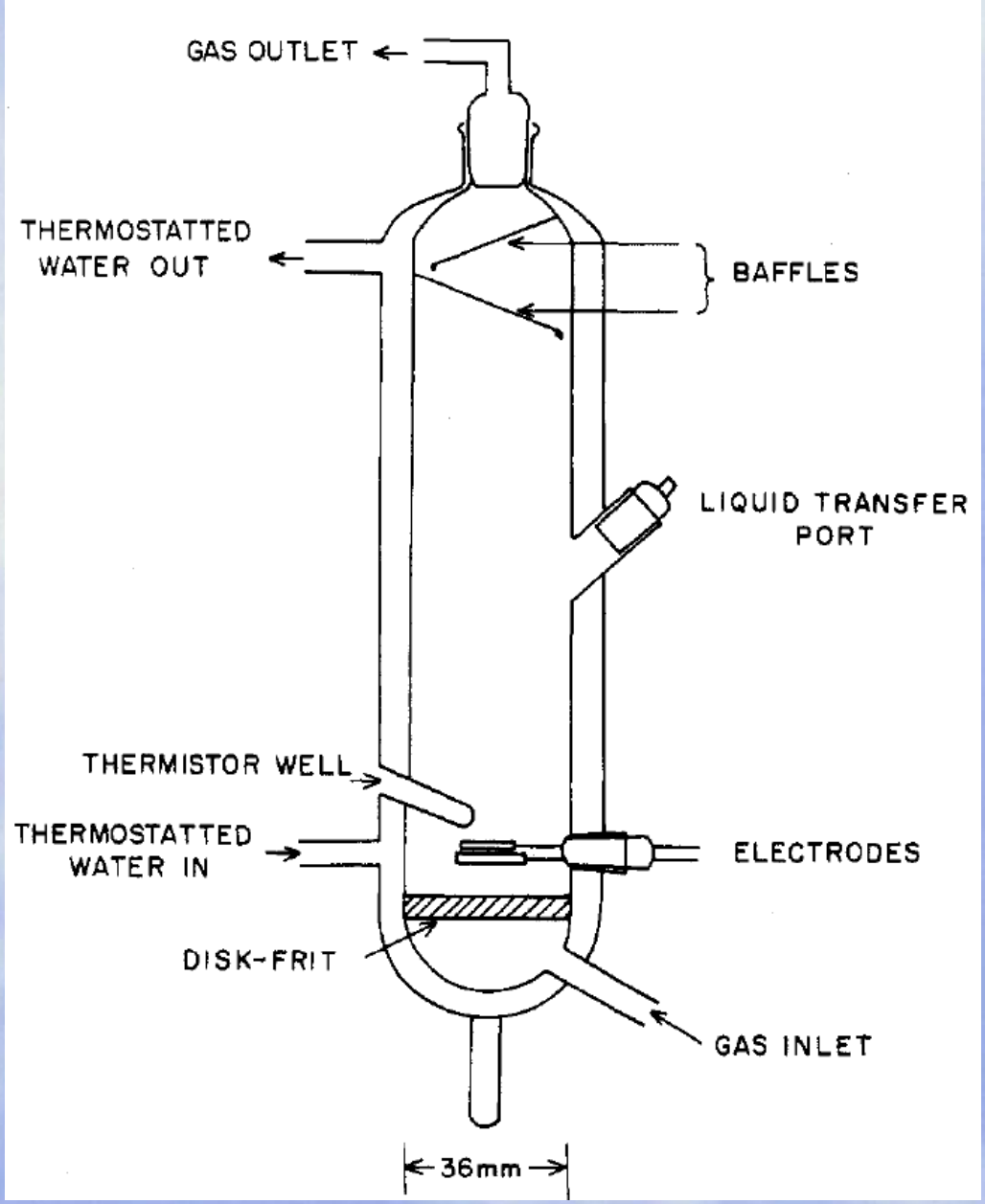
Time series in broken stratocumulus clouds.

Sulfate and light scattering coefficient are highly correlated and efficiently scavenged by liquid water clouds.

Atmospheric Environment, 1987

Reaction Kinetics of Nitrogen Dioxide with Liquid Water at Low Partial Pressure

Y.-N. Lee* and S. E. Schwartz



Reaction is second order in NO_2.

At low partial pressures characteristic of ambient NO_2 the reaction is insignificantly slow.

Nitric acid gets into rain by gas-phase oxidation of NO_2 followed by scavenging of HNO_3 by cloud drops and rain.

J. Phys. Chem., 1981

Acid Deposition: Unraveling a Regional Phenomenon

STEPHEN E. SCHWARTZ

Because sources of sulfur and nitrogen oxides distributed broadly across eastern North America have greatly overlapping zones of influence, it is difficult to determine detailed relations between emissions and the resulting acid deposition.

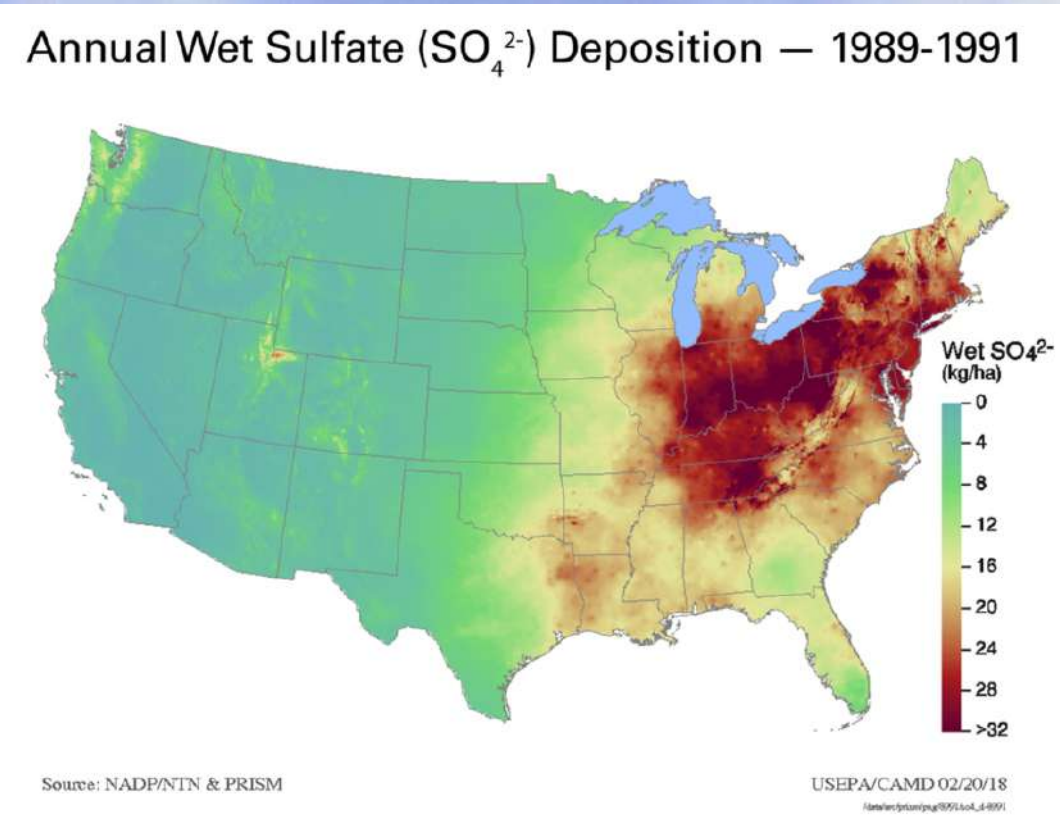
Because of the complexities of these processes and the wide range of the time and space scales involved, credible source-receptor relations for regional-scale acid deposition are not yet at hand.

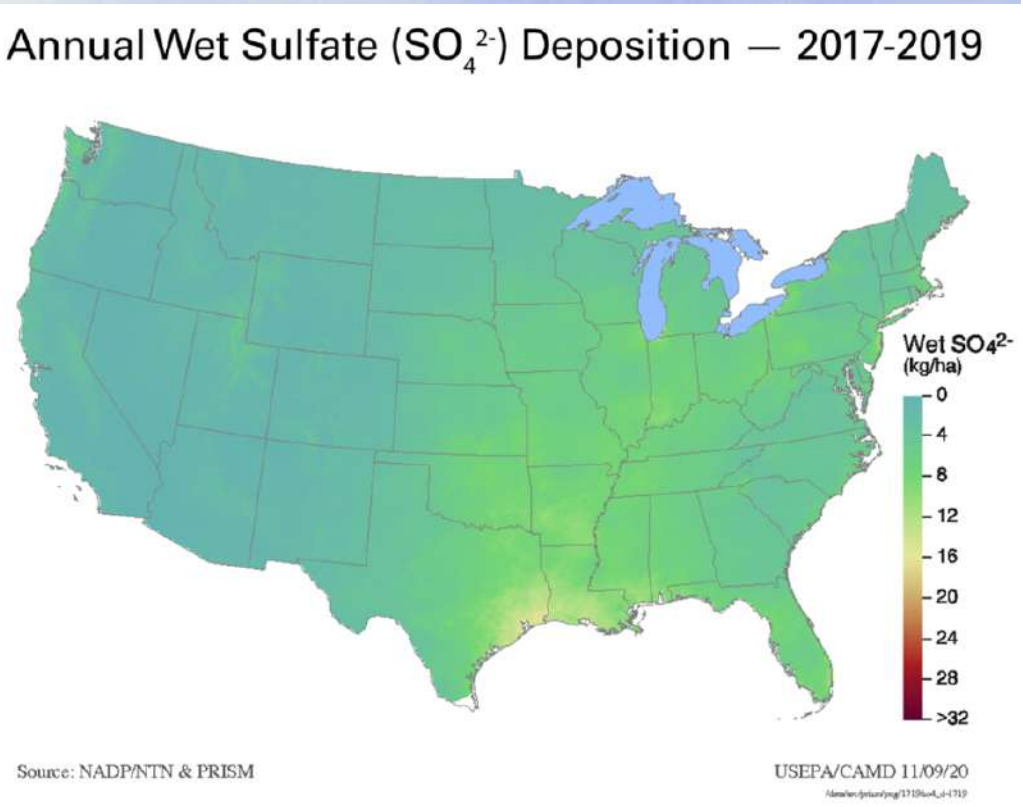
Consequently, near-term strategies for reducing acid deposition should be based on considerations other than detailed atmospheric source-receptor relations, but ***with confidence that regional deposition will be reduced equivalently to any reduction in regional emissions***.

Science, 1989

Paper was influential in drafting 1992 acid deposition amendments to Clean Air Act, particularly emissions trading provisions.

Sulfate deposition before and after Clean Air Act Amendments





The strategy worked.
A success story.

Arie Jan Haagen-Smit (1900 – 1977)

There are ominous signs that control technology alone is not able to cope with the ever-increasing growth in population and all its polluting activities. . . Today we realize that we have always been too timid in setting our goals. *PNAS*, 1970