Ron Giddings(http://graphicexchange.com/6Portfolio.html)

SEASALT AEROSOL PARTICLES

COUNTING ANGELS ON THE HEAD OF A PIN?

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Workshop on
Sea Spray Aerosol Production

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http:// www. ecd. bnl. gov/ steve/ schwartz. html

IMPORTANCE OF SEA SALT AEROSOL TO CLIMATE CHANGE

Aerosols — the key uncertainty in radiative forcing of climate change over the industrial period.

Role of ***sea salt*** aerosol?

Understanding/quantifying climate influences of other aerosol species

Attribution of aerosol radiative influences to SSA and non-SSA species.

Evaluating CTM calculations of aerosol optical depth and other properties

Decreasing the "wiggle room" in modeling aerosol forcing.

Influencing forcing of climate change by other aerosol species

Direct forcing.

Indirect forcing.

Forcing of climate change by SSA

Increased SSA production in a greenhouse warmed world?

IMPORTANCE OF SSA IN UNDERSTANDING AND QUANTIFYING *CLIMATE INFLUENCES* OF AEROSOL SPECIES OTHER THAN SSA

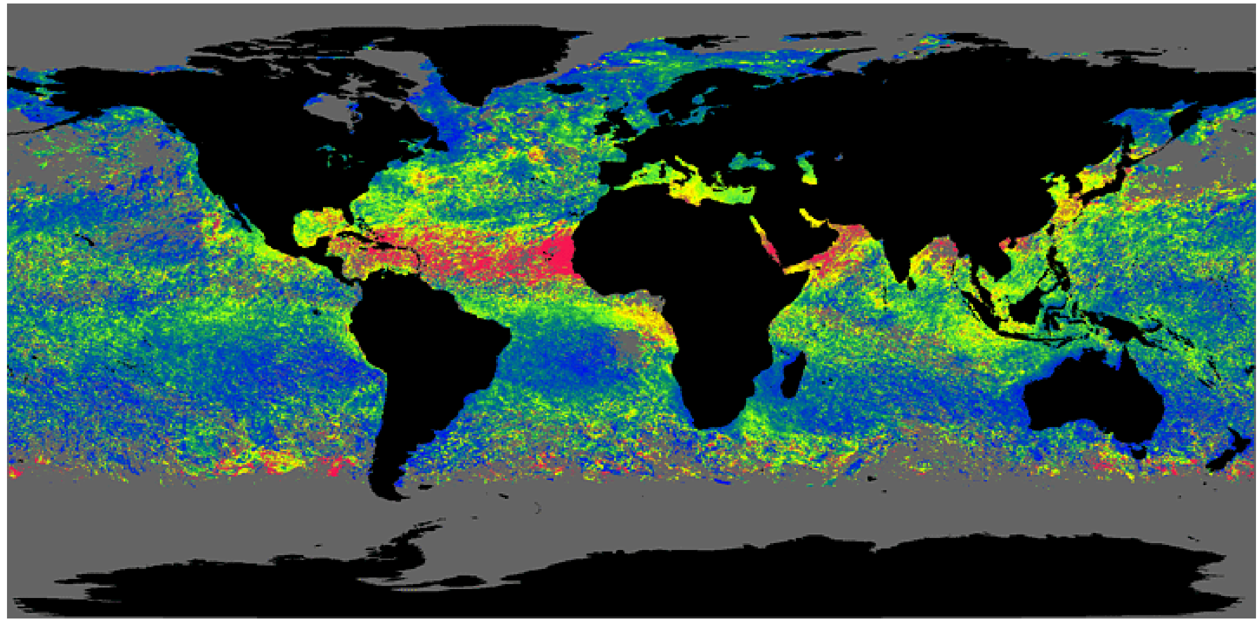
MONTHLY AVERAGE AEROSOL JUNE 1997

Polder radiometer on Adeos satellite

Optical Thickness τ

$\lambda = 865$ nm

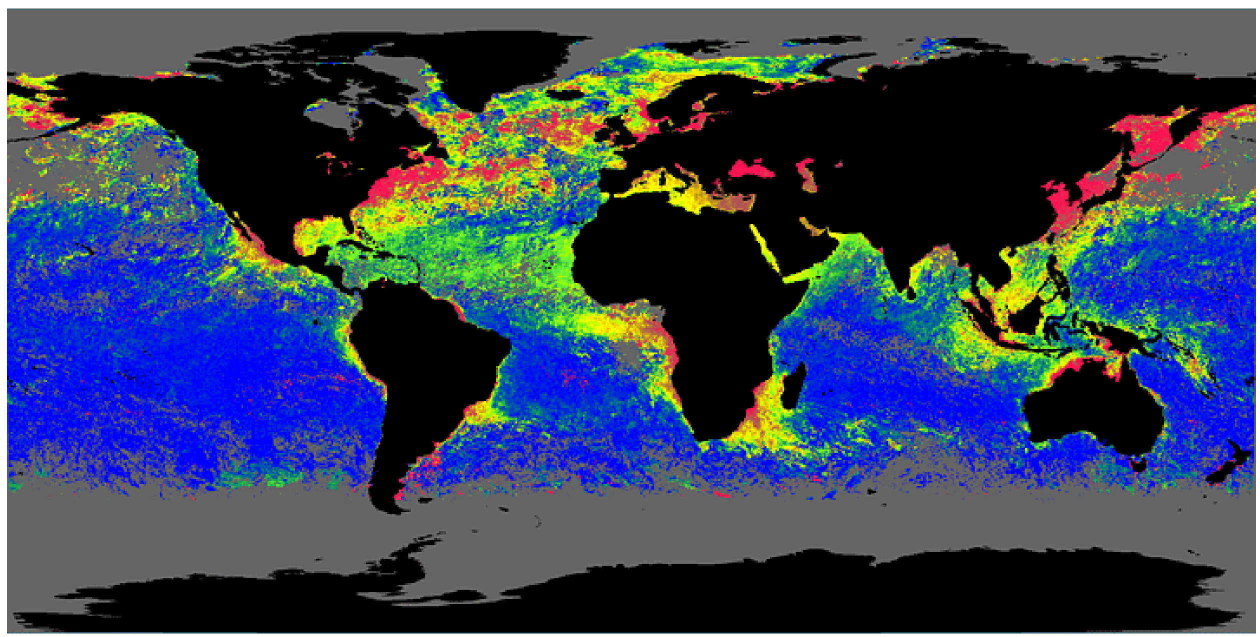
0 — 0.5



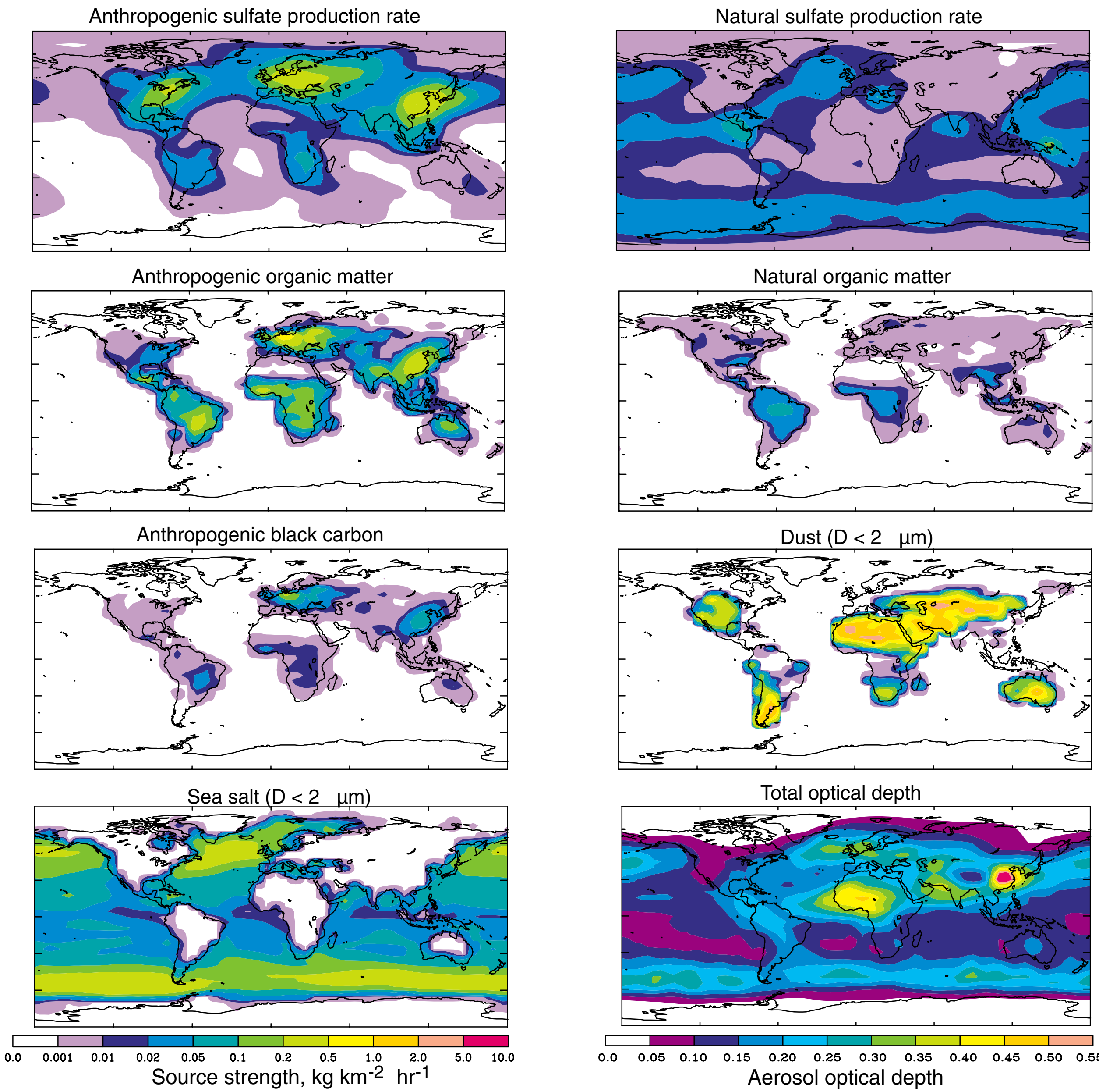
Ångström Exponent α

$$\alpha = -d \ln \tau / d \ln \lambda$$

-0.2 — 1.2



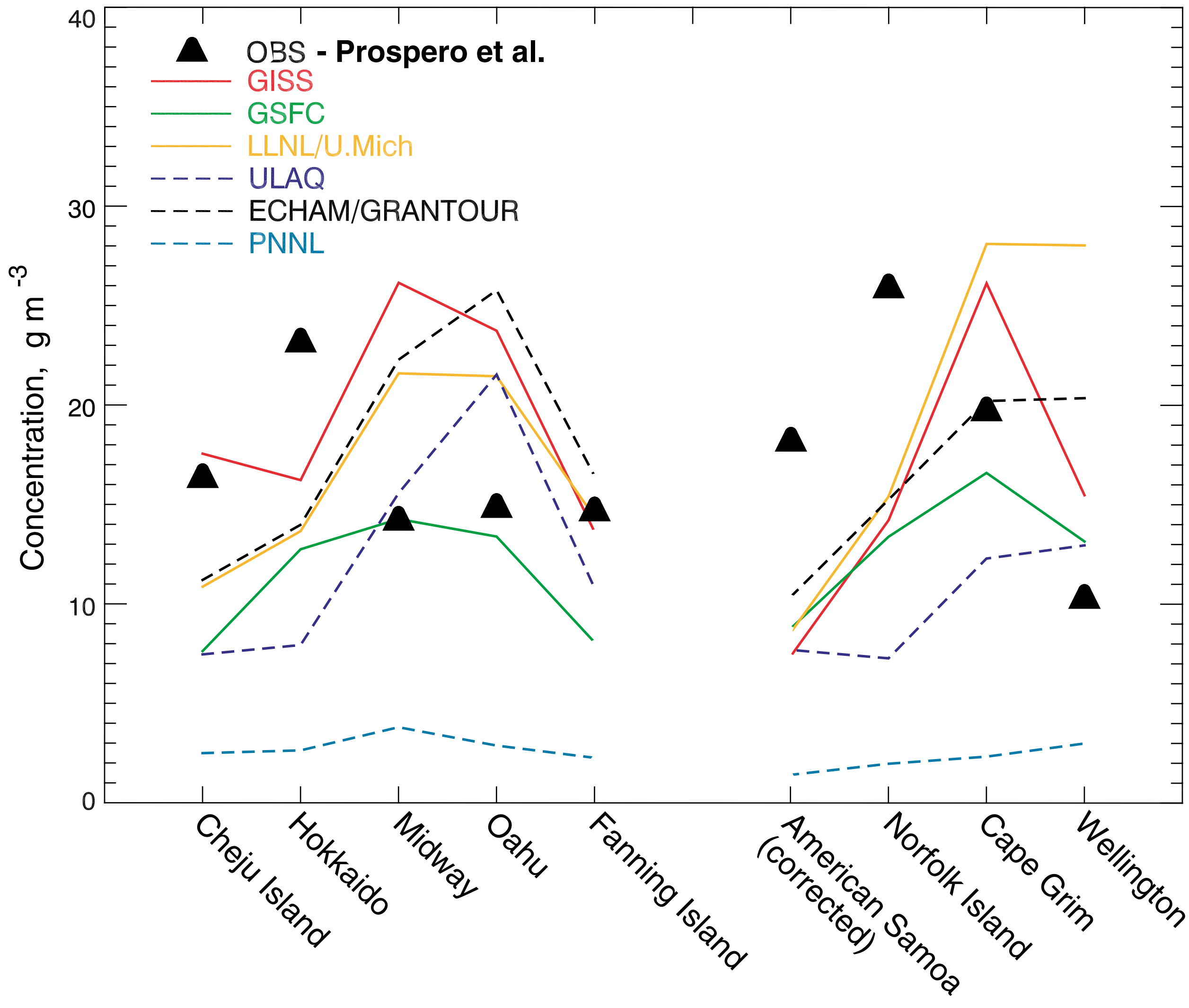
SOURCE STRENGTHS OF KEY AEROSOL TYPES AND AEROSOL OPTICAL DEPTH (IPCC, 2001)



SEASALT AEROSOL MASS CONCENTRATION

Modeled and observed annual concentrations vs. location

From IPCC (2001) intercomparison

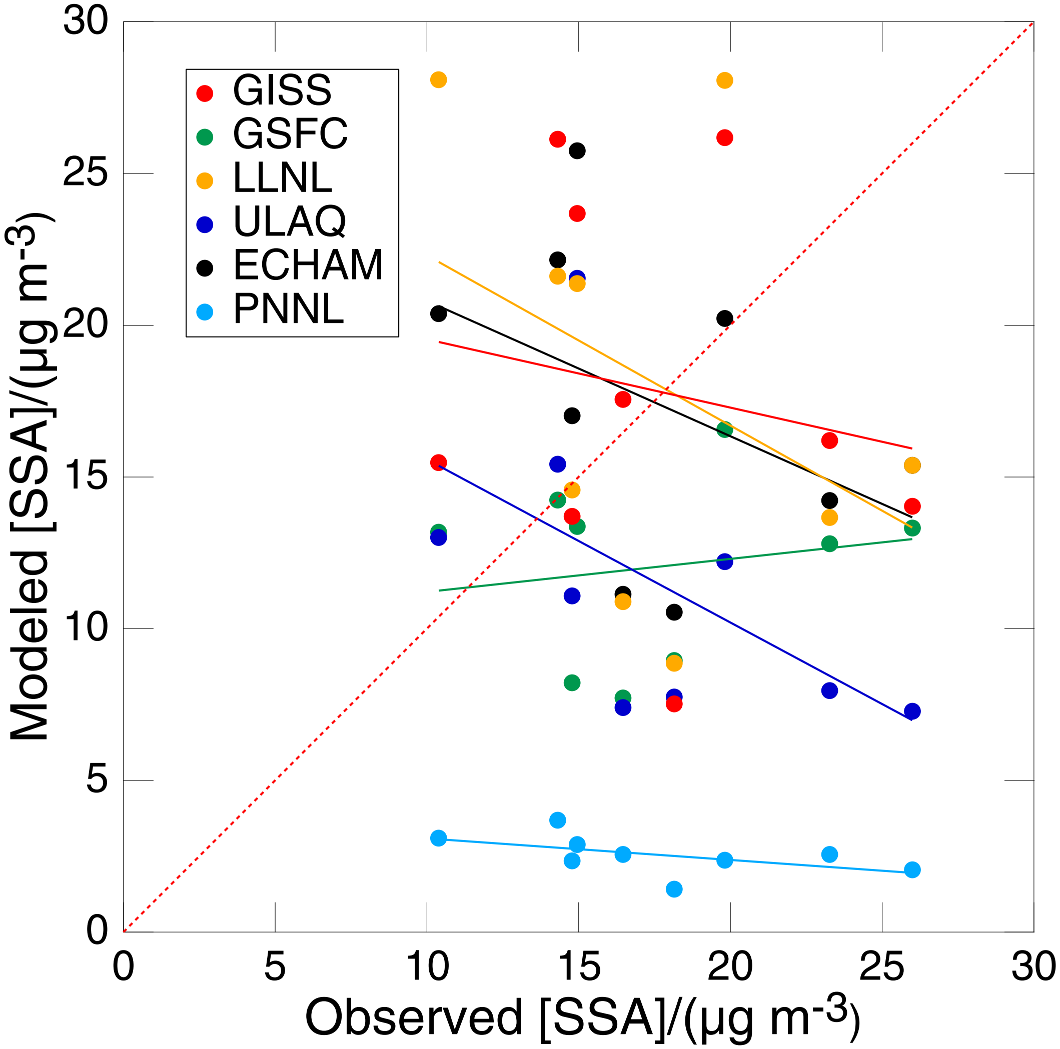


All models used the Gong et al. (1997) source function based on Canadian Climate Model winds.

SEASALT AEROSOL MASS CONCENTRATION

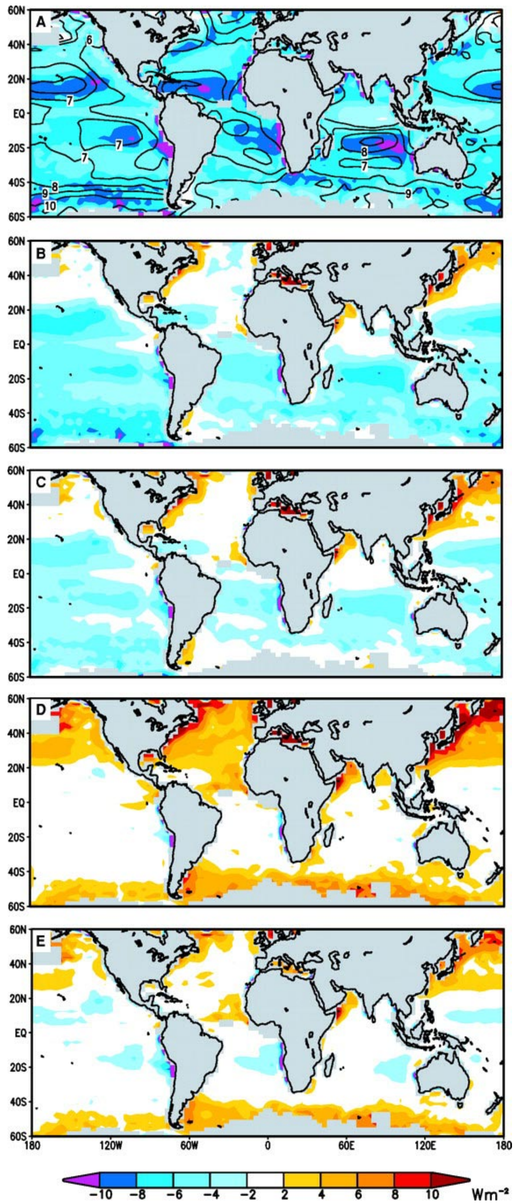
Modeled vs. observed annual concentrations

From IPCC (2001) intercomparison



SENSITIVITY OF MODELED TOA FLUX TO SSA

Difference between modeled and measured annual TOA outgoing shortwave radiation -- *Haywood, Ramaswamy & Soden, Science, 1999*



No aerosol

Pronounced deficit in modeled flux in areas of high surface winds.

All aerosols ***except*** sea salt

Difference reduced by factor of 2 indicates importance of non-sea-salt aerosols.

All aerosols; ***low*** sea salt

Low sea-salt aerosol burden leads to further improvement.

All aerosols; ***high*** sea salt

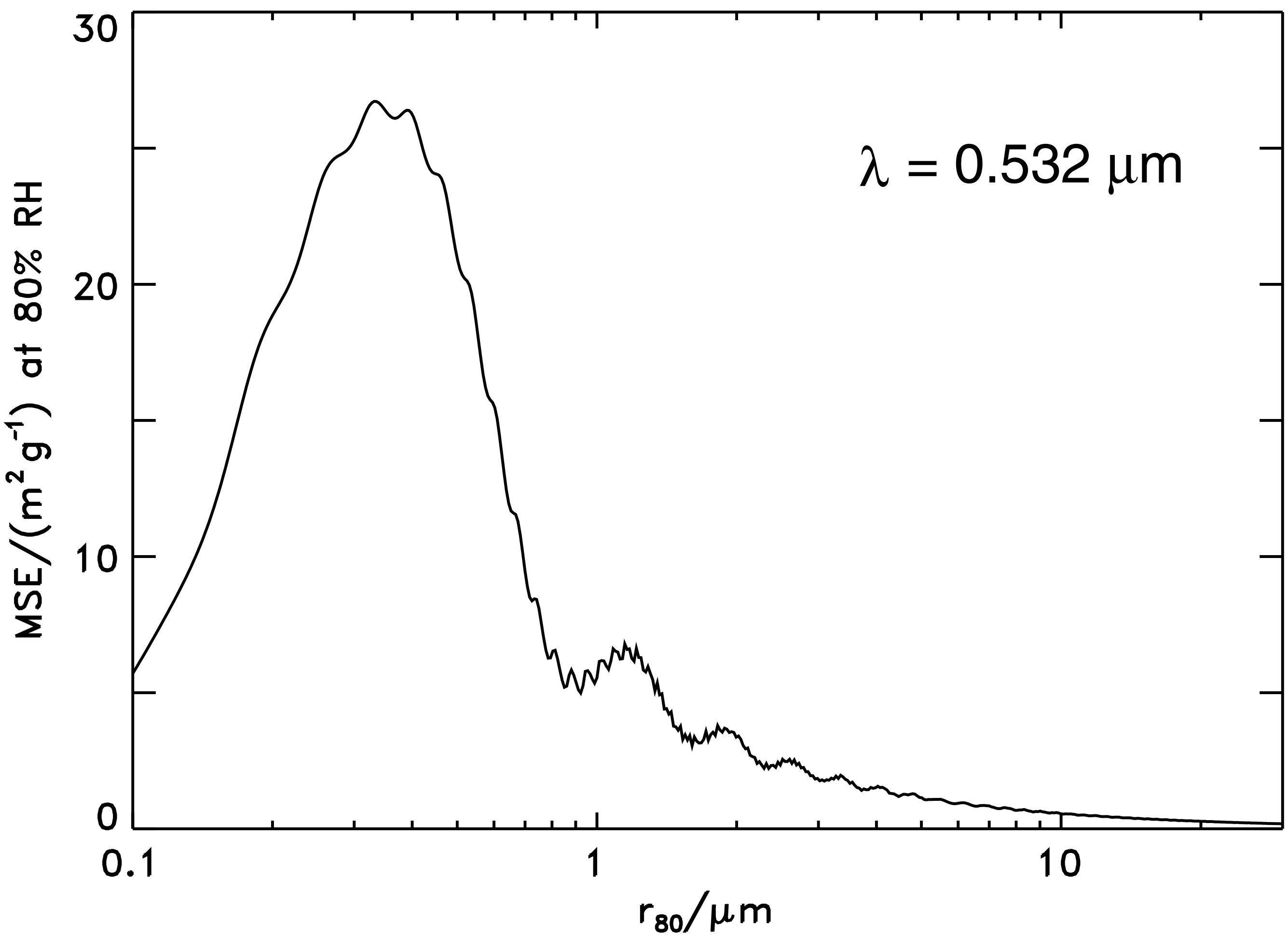
High sea-salt burden eliminates difference in SH but overestimates mid-to-high latitude NH oceans.

All aerosols ***except*** sulfate; ***high*** sea salt

Ignoring sulfate yields good agreement almost everywhere. Anthropogenic sulfate aerosol over oceans may be overestimated.

SEASALT AEROSOL
MASS SCATTERING EFFICIENCY

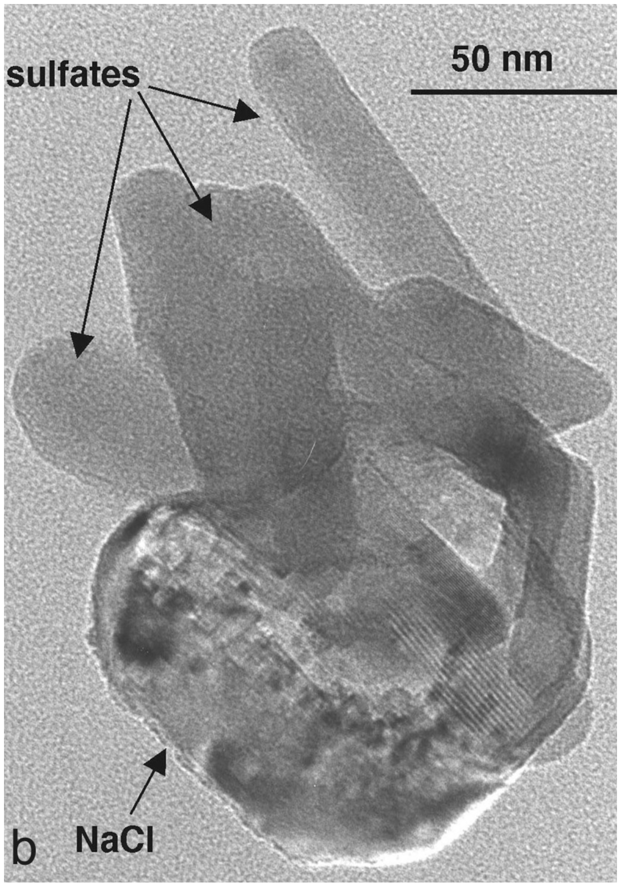
At 80% RH; dependence on particle radius at 80% RH

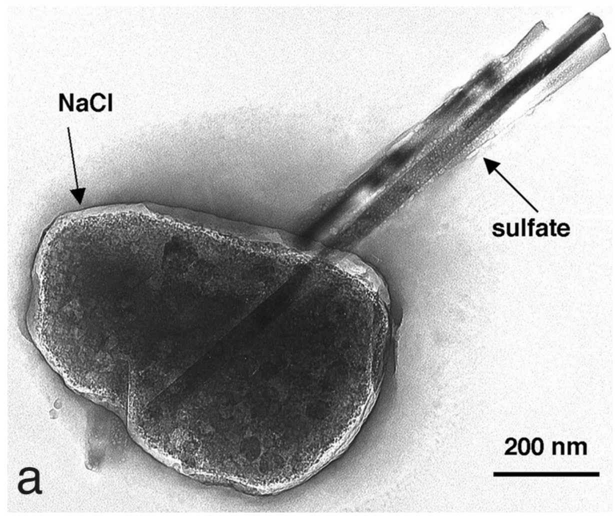


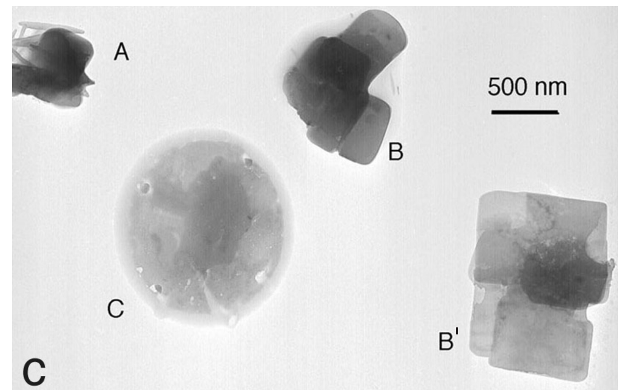
The mass scattering efficiency depends strongly on particle radius.

IMPORTANCE OF SSA IN INFLUENCING *FORCING OF CLIMATE CHANGE* BY AEROSOL SPECIES OTHER THAN SSA

UPTAKE OF SULFATE AND NITRATE BY SEA SALT







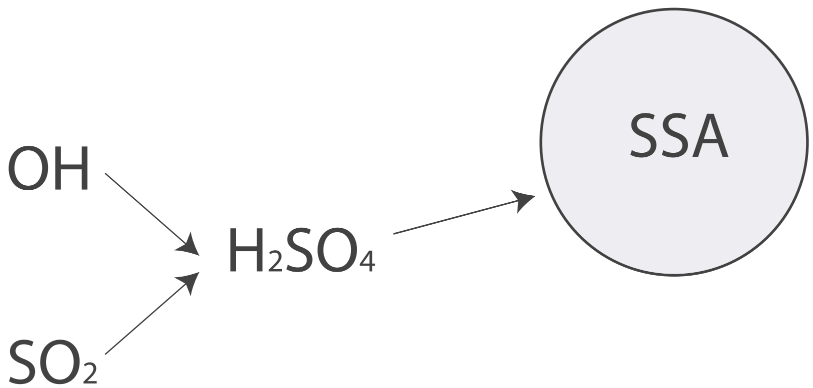
A, nitrate, partial conversion
B, B' sulfate
C, nitrate

Buseck and Pósfai, PNAS, 1999

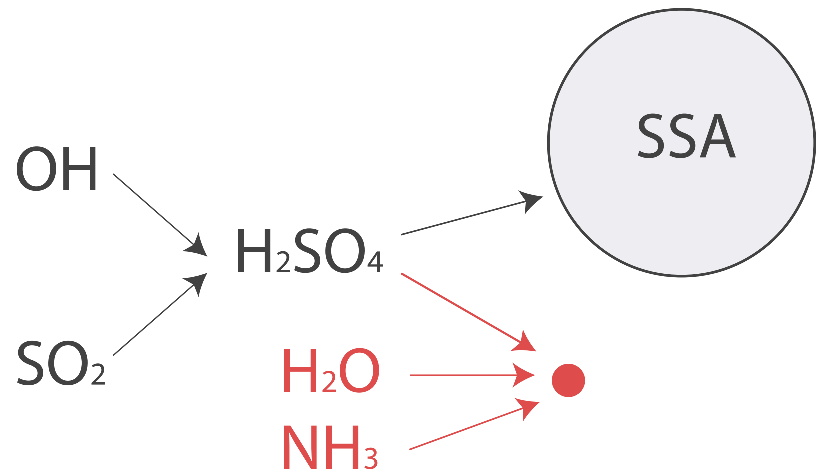
SUPPRESSION OF NUCLEATION BY SSA

By providing a sink for H_2SO_4, SSA particles can keep concentrations sufficiently low to suppress new particle formation, changing the size distribution of the concentration of the resultant marine aerosol.

If $[H_2SO_4]$ is ***below*** the nucleation threshold, then nucleation is suppressed.



If $[H_2SO_4]$ ***exceeds*** the nucleation threshold, nucleation occurs forming new particles.



Nucleation is suppressed if $[H_2SO_4] < [H_2SO_4]^* \approx 3 \times 10^6$ cm^{-3} (*Napari et al., JGR, 2002*).

SOURCES AND SINKS OF H_2SO_4 AND CRITICAL SSA CONCENTRATION

$$OH + SO_2 \xrightarrow{k_r} H_2SO_4$$

$$H_2SO_4 + SSA \xrightarrow{k_{mt}} H_2SO_4 \cdot SSA$$

At steady state $\dfrac{dH_2SO_4}{dt} = 0 = k_r[OH][SO_2] - k_{mt}[H_2SO_4][SSA]$.

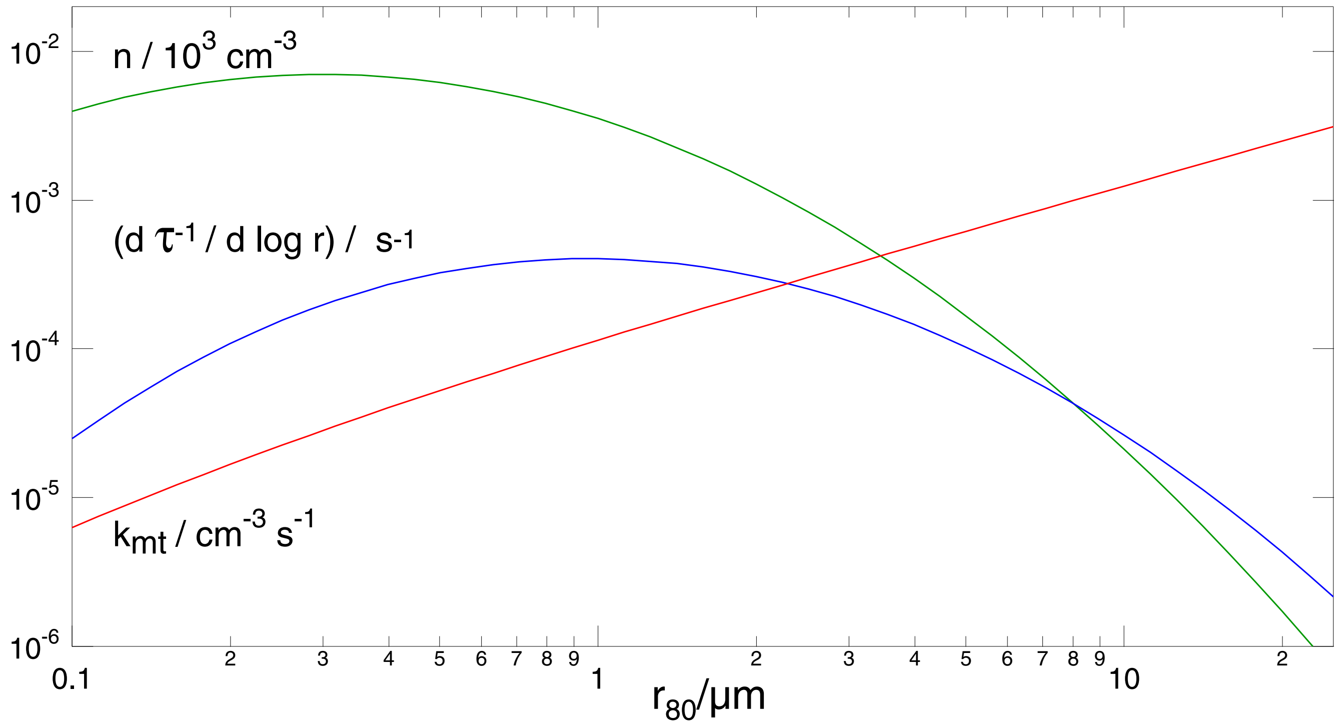
Nucleation is suppressed if $k_{mt}[SSA] > \dfrac{k_r[OH][SO_2]}{[H_2SO_4]^*}$.

For diffusion limited uptake $k_{mt}[SSA] = 4\pi D_g R$ where D_g = diffusion coefficient and R = SSA "radius concentration," $R = \int r(dn / d\log r)d\log r$.

For [OH] = 3×10^6 cm^{-3} and SO_2 = 0.02 nmol mol^{-1} (ppb) the critical radius concentration $R^* \approx 4$ μm cm^{-3}, typical of SSA (1-10 μm cm^{-3}).

UPTAKE OF CONDENSABLE GASES ON SEA SALT AEROSOL

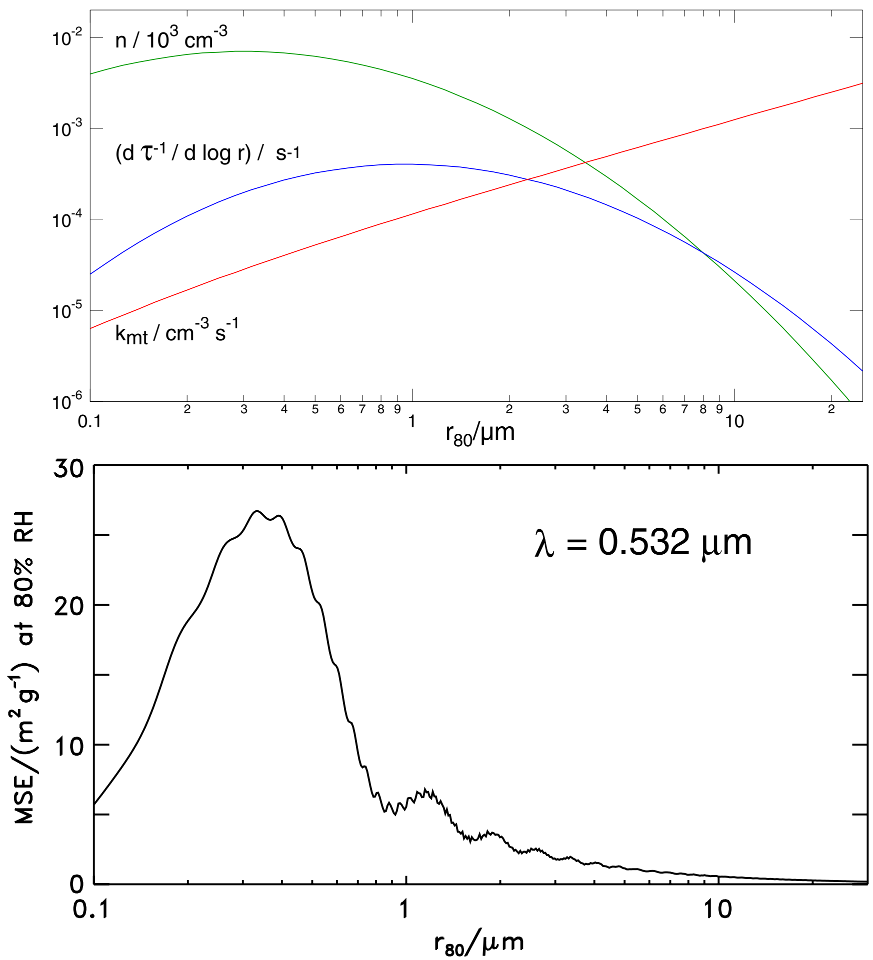
Dependence on particle radius for "canonical" size distribution; RH = 80%



Mass adds preferentially near r_{80} = 1 μm.

UPTAKE OF CONDENSABLE AND REACTIVE GASES ON SEA SALT AEROSOL

Dependence on particle radius for “canonical” size distribution; RH = 80%

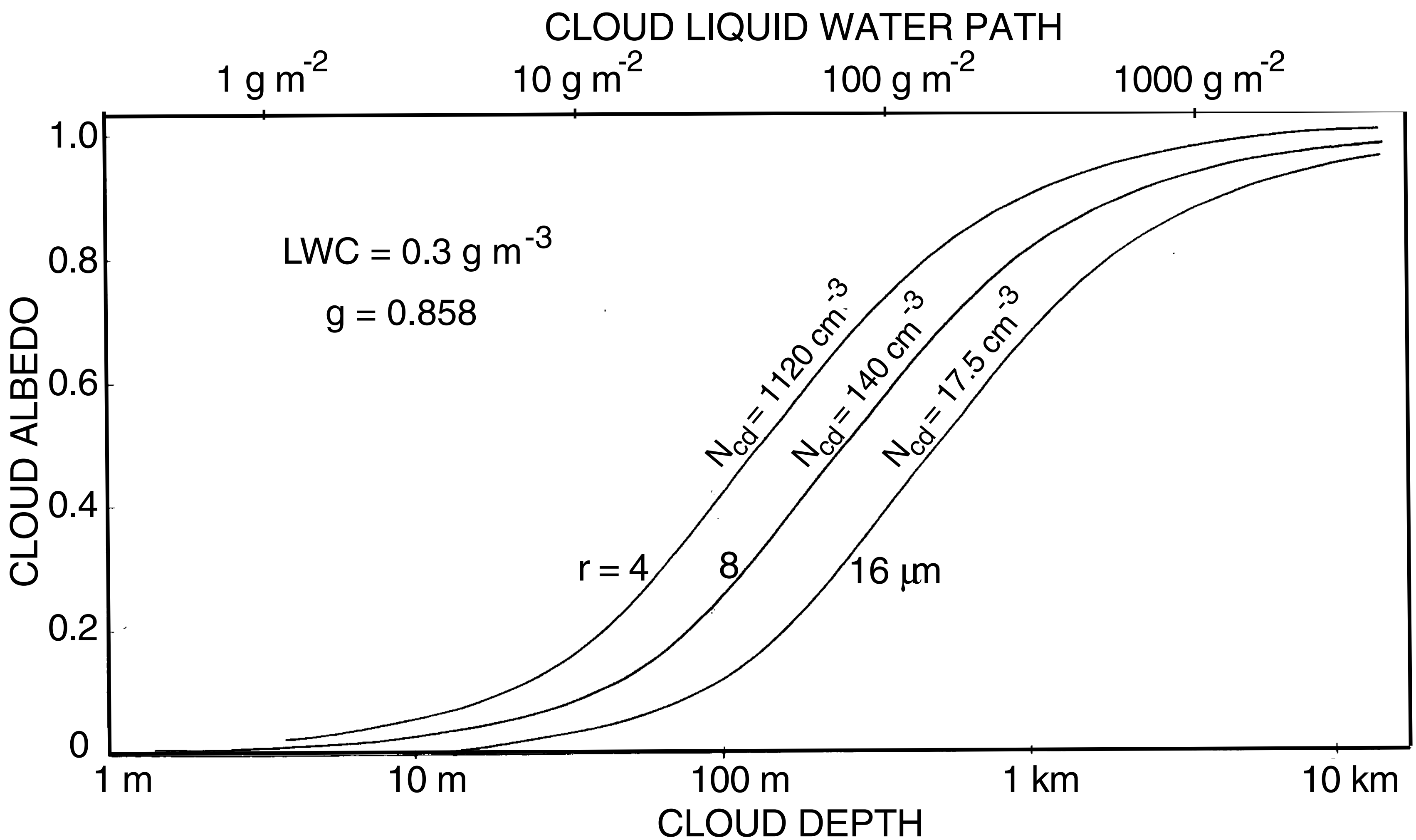


In clear air mass adds preferentially near r_{80} = 1 μm.

In clouds mass adds preferentially near r_{80} = 0.3 μm.

DEPENDENCE OF CLOUD ALBEDO ON CLOUD DEPTH

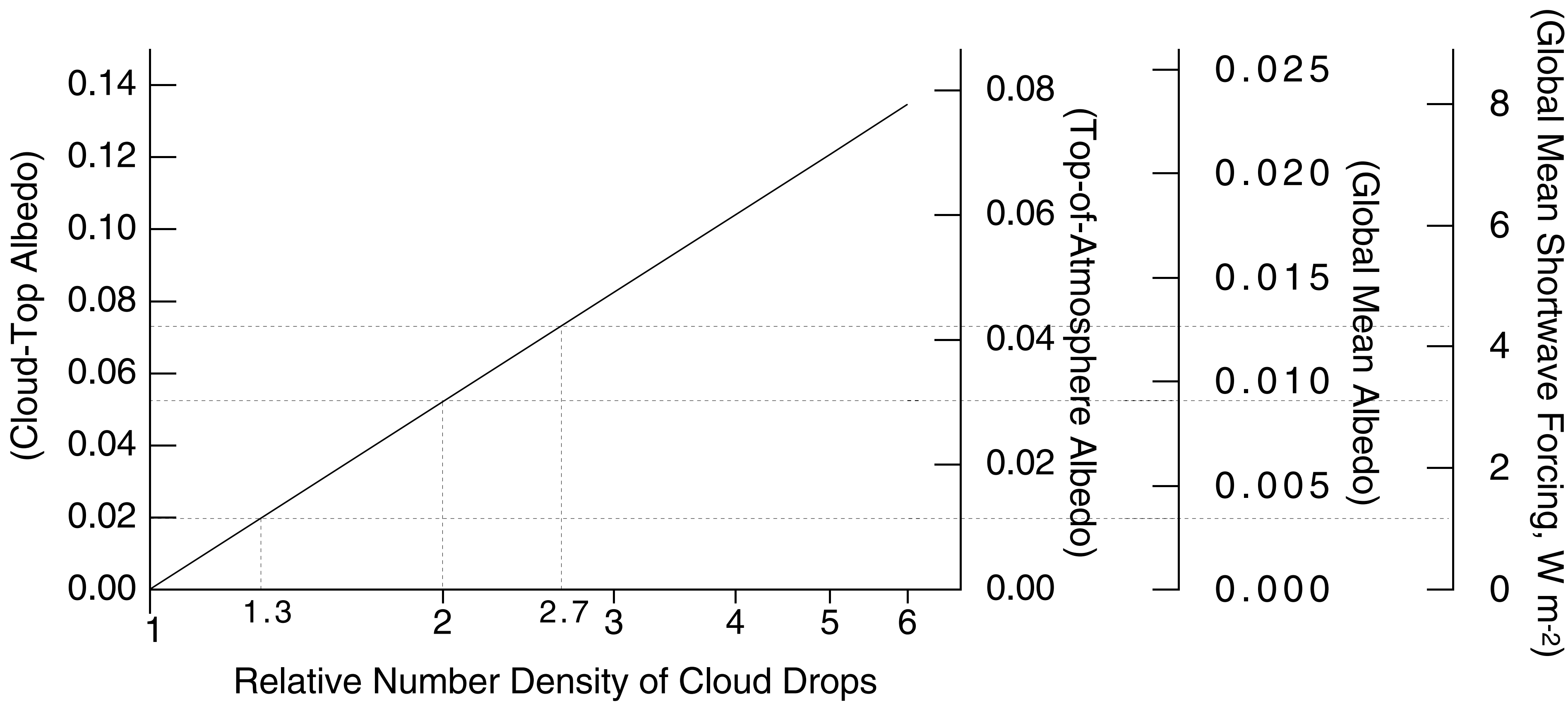
Influence of Cloud Drop Radius and Concentration



Twomey, *Atmospheric Aerosols*, 1977

For a given liquid water path, cloud albedo is highly sensitive to cloud drop number concentration or radius.

SENSITIVITY OF ALBEDO AND FORCING TO CLOUD DROP CONCENTRATION



Schwartz and Slingo (1996)

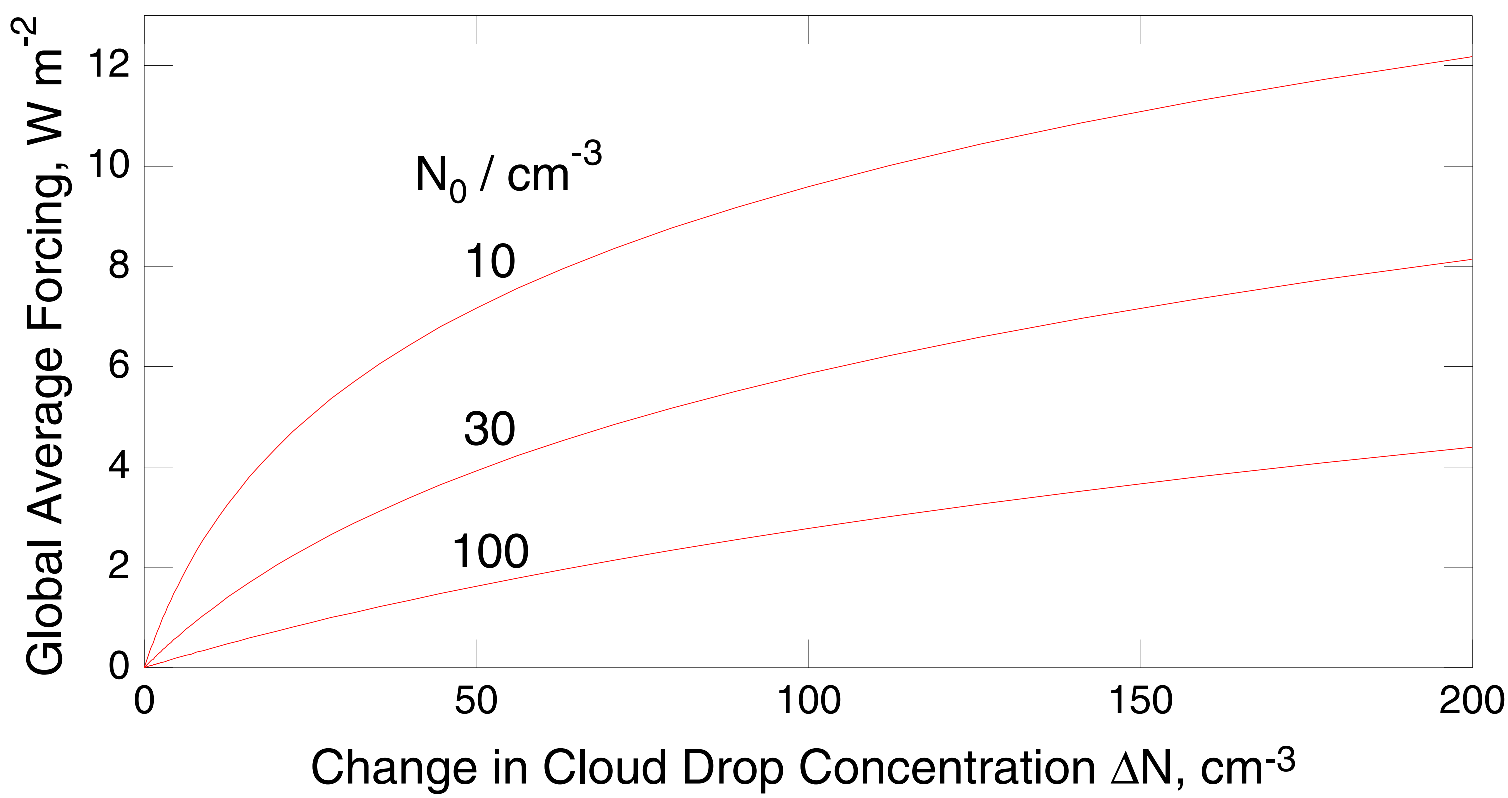
Indirect forcing is highly sensitive to small perturbations in cloud drop concentration.

A 30% increase in cloud drop concentration results in a forcing of ~1 W m^{-2}.

INDIRECT (TWOMEY) FORCING

Dependence on incremental cloud drop concentration ΔN and Sensitivity to initial cloud drop concentration N_0

$$F\,/\,(\mathrm{W\ m^{-2}}) \approx 4\ln\left(\frac{N_0+\Delta N}{N_0}\right) = 4\ln\left(1+\frac{\Delta N}{N_0}\right)$$



Aerosol indirect forcing is highly sensitive to background CCN concentration.

RESEARCH REQUIREMENTS FOR SSA PRODUCTION

Accurate SSA mass production flux and its dependence on controlling parameters.

Necessary to model SSA *mass concentration* (but insufficient).

Accurate size-dependent SSA production flux and its dependence on controlling parameters.

Necessary to model SSA *size dependent concentration*

Necessary to determine *optical properties and radiative influences*.

Necessary to model SSA influences on *clouds and precipitation*.

Essential to model ***direct effects*** of anthropogenic aerosols.

Essential to model ***indirect effects*** of anthropogenic aerosols.

The sensitivity of aerosol direct and indirect forcing to size-dependent SSA concentration necessitates accuracies of $\overset{\times}{\div}$ 2 or better.