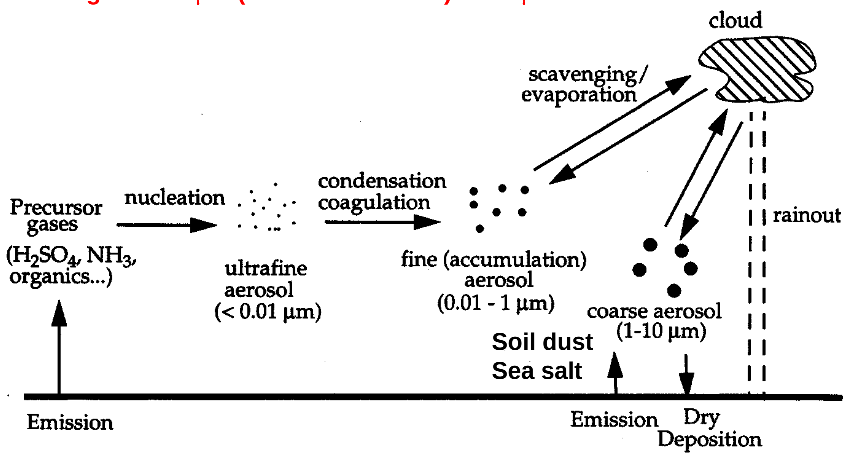
# ORIGIN OF TROPOSPHERIC AEROSOL

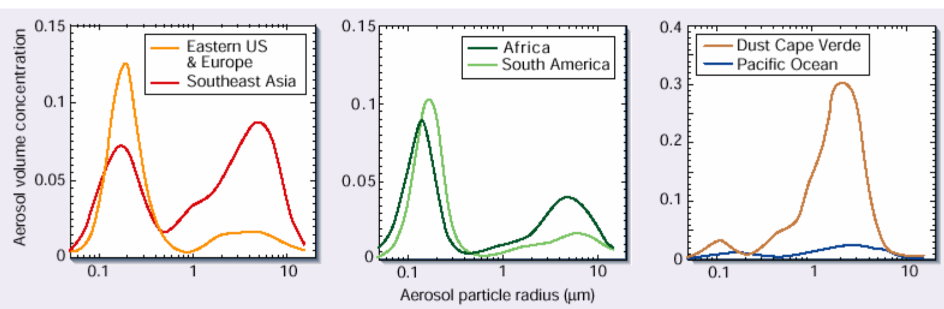
**Aerosol: dispersed condensed phases suspended in a gas**
**Size range: 0.001 μm (molecular cluster) to 10 μm**




**Environmental importance: radiative balance, health (respiration), visibility, cloud formation, heterogeneous reactions, delivery of nutrients…**

*Jacob, Introduction to Atmospheric Chemistry, 2000.*

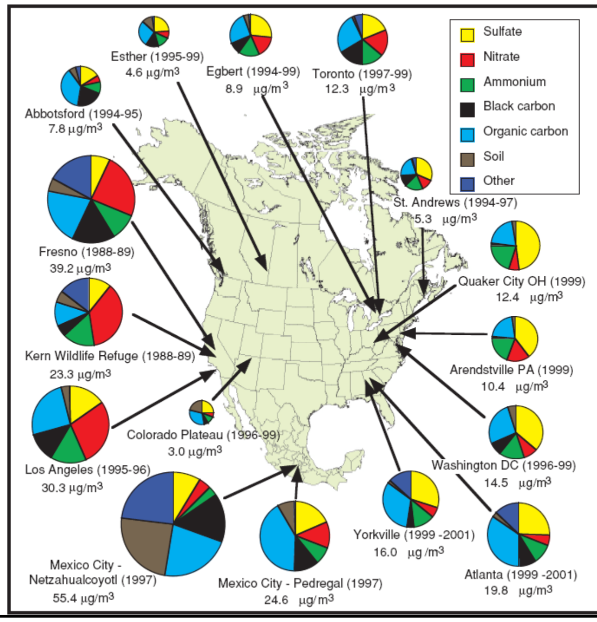
# Climatology of ambient aerosol size distribution




**Kaufman et al., Nature, 2002.**

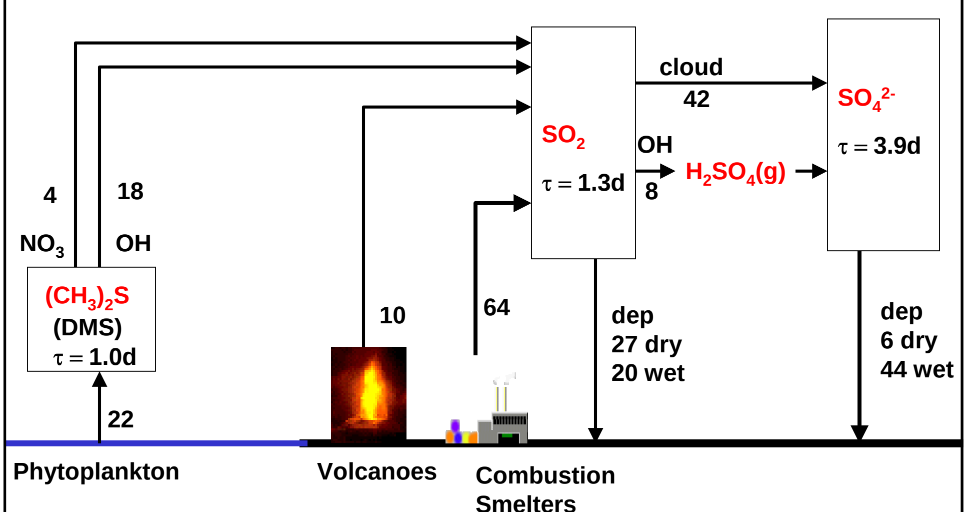
## FINE AEROSOL COMPOSITION IN NORTH AMERICA

**Annual mean $PM_{2.5}$ concentrations (NARSTO, 2004)**



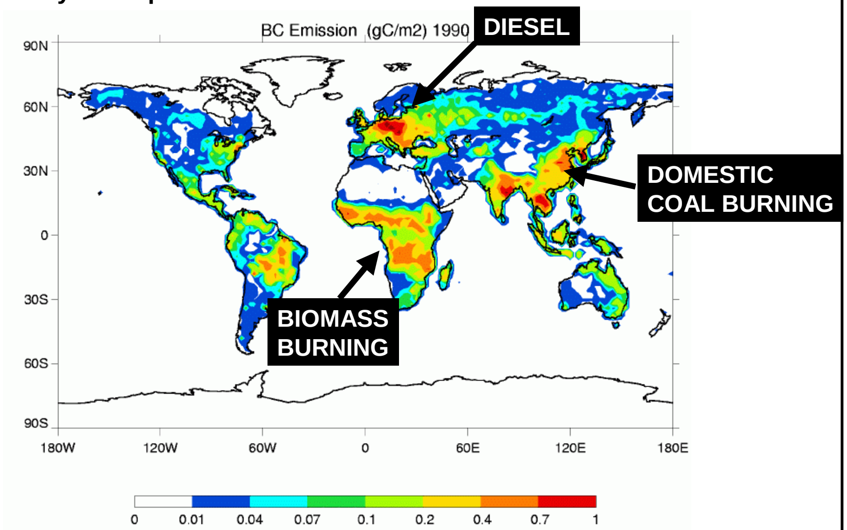

## GLOBAL SULFUR BUDGET

## (flux terms in Tg S yr$^{-1}$)



# BLACK CARBON EMISSIONS

**Produced by incomplete combustion**

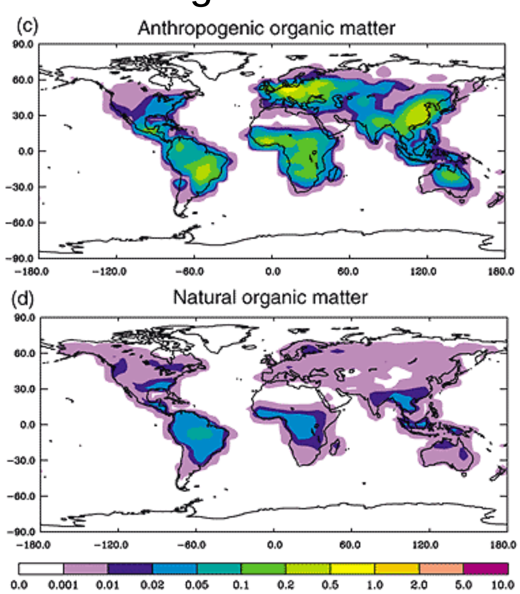



**Chin et al. [2000]**

# Source distribution of organic aerosols

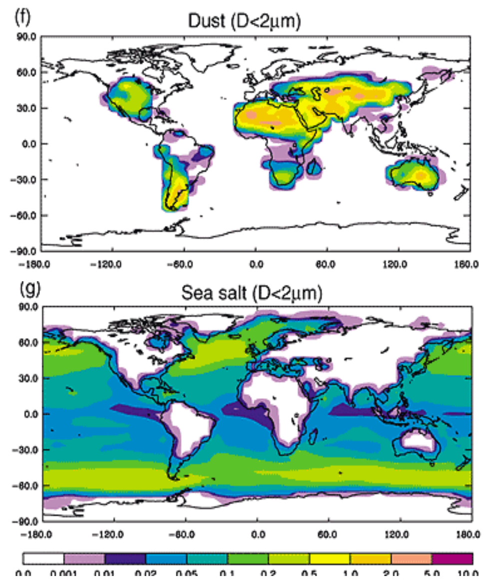
primary (biomass burning + fossil fuels) and secondary

secondary organic aerosols from biogenic VOC oxidation




***Annual average source strength in kg km$^{-2}$ hr$^{-1}$***

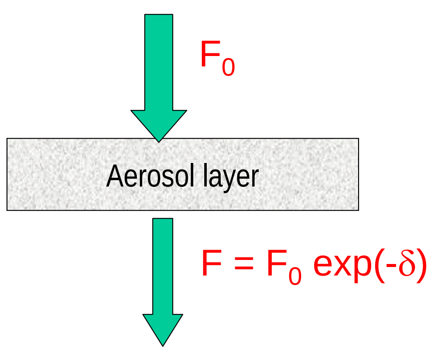
## Dust and sea-salt aerosols




***Annual average source strength in kg km$^{-2}$ hr$^{-1}$***

## Aerosol optical depth

- Attenuation of sunlight by particles (scattering + absorption)




Aerosol optical depth:

$\delta = n\,(\sigma_{abs} + \sigma_{scat})\,L$

n: number density of aerosols

$\sigma_{abs/scat}$: absorption and scattering cross sections

L: thickness of aerosol layer

# Atmospheric brown clouds



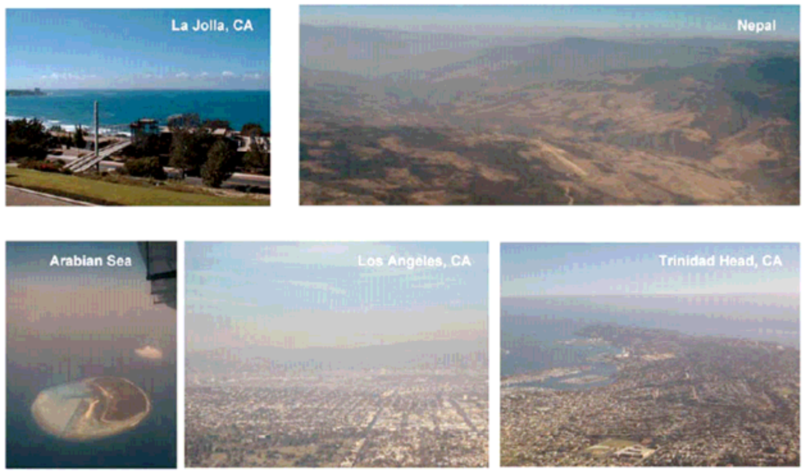
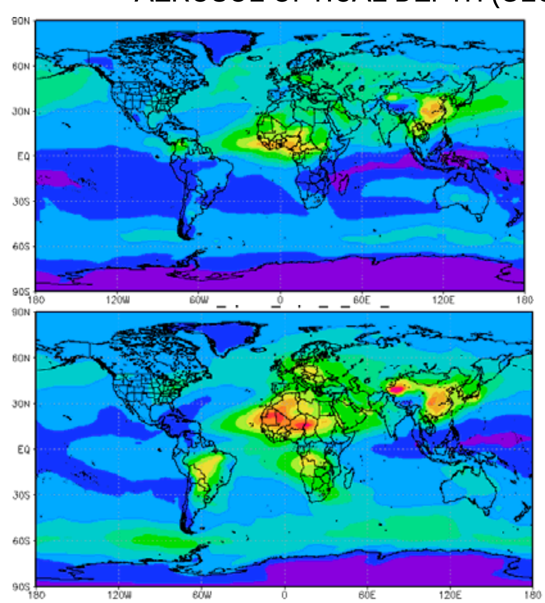



**Figure 3.** Photographs of atmospheric brown clouds from regions included in this study.

*J. Geophys. Res.*, *112*, D22S21, doi:10.1029/2006JD008124.

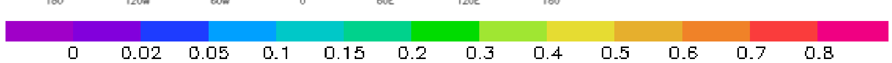
# AEROSOL OPTICAL DEPTH (GLOBAL MODEL)



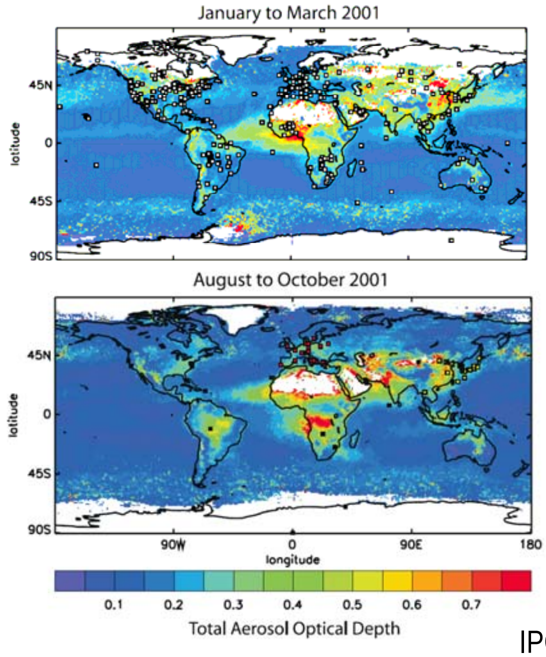

Jan-Mar 2001

*Globally averaged aerosol optical depth $\delta = 0.1$*

Aug-Oct 2001

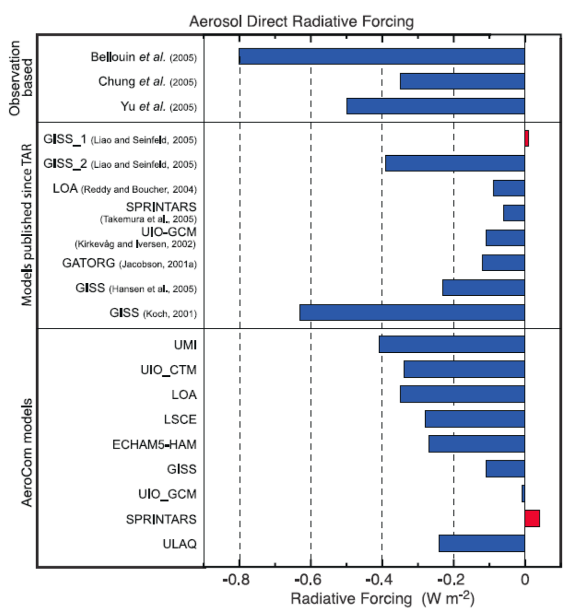


## Aerosol optical depth viewed from satellite (MODIS)




IPCC 2007, Fig 2.11

# Aerosol Direct Radiative Forcing



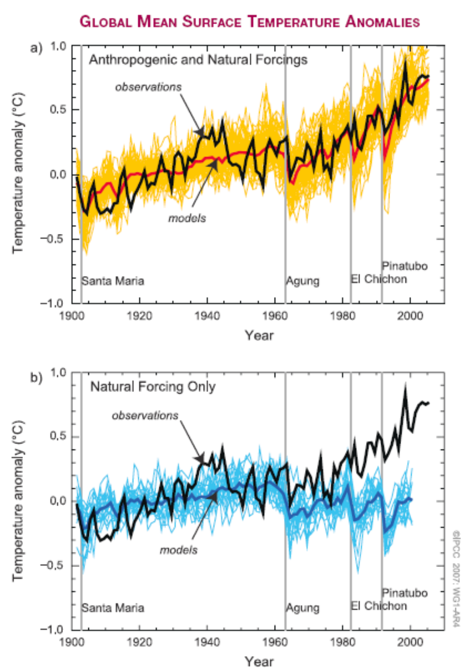

Best estimate: -0.5±0.4 $Wm^{-2}$

IPCC(2007), Fig. 2.13

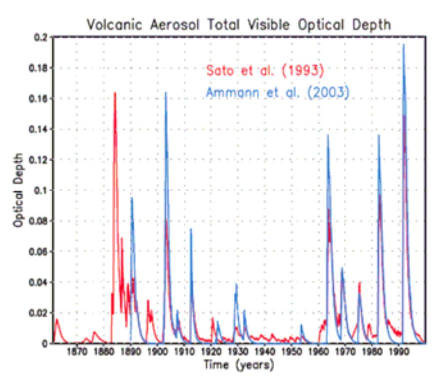
# Radiative forcing for individual aerosols

| | Global mean radiative forcing (W m⁻²)[a] | | | |
|---|---|---|---|---|
| | SAR (1750–1993) | TAR (1750–1998) | AR4 (1750–2005) | Summary comments on changes since the TAR |
| Direct sulphate aerosol | −0.40 [2x] | −0.40 [2x] | −0.40 [±0.20] | Better constrained |
| Direct fossil fuel aerosol (organic carbon) | Not evaluated | −0.10 [3x] | −0.05 [±0.05] | Re-evaluated to be weaker |
| Direct fossil fuel aerosol (BC) | +0.10 [3x] | +0.20 [2x] | +0.20 [±0.15] | Similar best estimate to the TAR. Response affected by semi-direct effects |
| Direct biomass burning aerosol | −0.20 [3x] | −0.20 [3x] | +0.03 [±0.12] | Re-evaluated and sign changed. Response affected by semi-direct effects |
| Direct nitrate aerosol | Not evaluated | Not evaluated | −0.10 [±0.10] | Newly evaluated |
| Direct mineral dust aerosol | Not evaluated | −0.60 to +0.40 | −0.10 [±0.20] | Re-evaluated to have a smaller anthropogenic fraction |
| **Total direct aerosol** | **Not evaluated** | **Not evaluated** | **−0.50 [±0.40]** | **Newly evaluated** |
| **Cloud albedo effect** | **0 to −1.5 (sulphate only)** | **0.0 to −2.0 (all aerosols)** | **−0.70 [−1.1, +0.4] (all aerosols)** | **Best estimate now given** |

IPCC (2007) Table 2.12

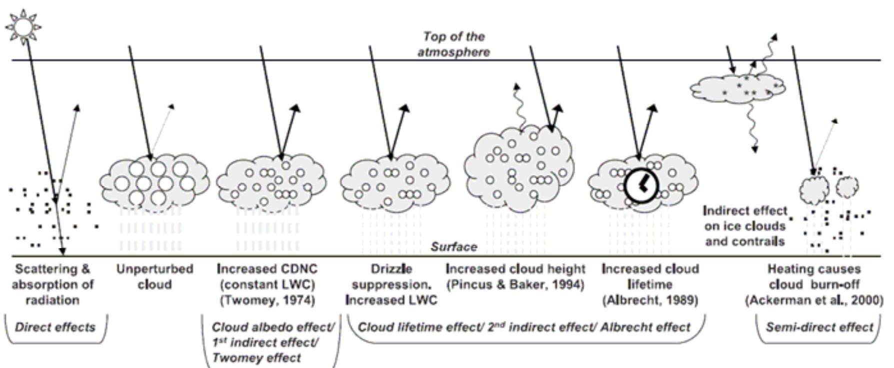



## Climate effects of aerosols through volcanic eruptions




IPCC, TS Fig.23

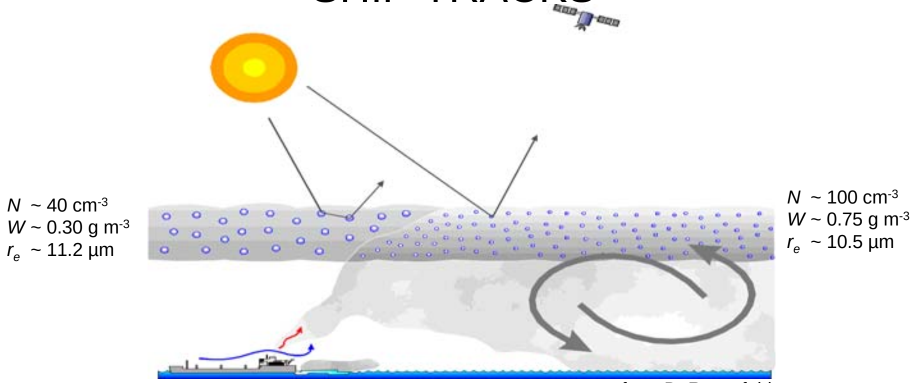
Aerosols Indirect Effects:
aerosols modify microphysical properties of clouds
→ changes in radiative properties and lifetimes of clouds




-0.5W/m²　　-0.7W/m²

IPCC (2007), Fig 2.10

# EVIDENCE OF INDIRECT EFFECT: SHIP TRACKS




from D. Rosenfeld

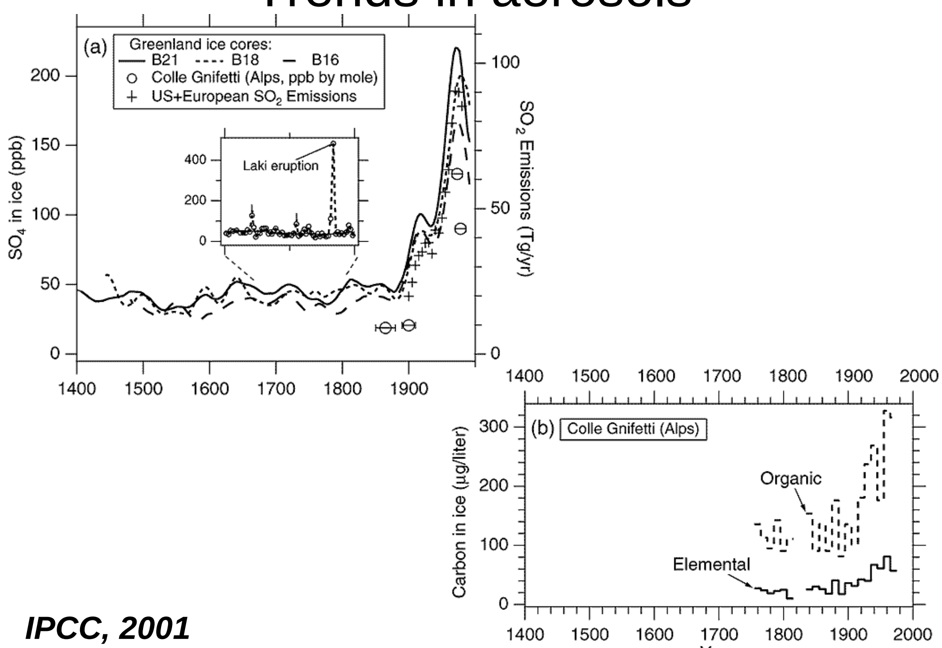
- Particles emitted by ships increase concentration of cloud condensation nuclei (CCN)
- Increased CCN increase concentration of cloud droplets and reduce their avg. size
- Increased concentration and smaller particles reduce production of drizzle
- Liquid water content increases because loss of drizzle particles is suppressed
- Clouds are *optically thicker* and brighter along ship track

# SATELLITE IMAGES OF SHIP TRACKS

Ship tracks off Europe's Atlantic coast.
NASA/MODIS Jan 27 2003

Ship tracks off Western US
NASA/MODIS June 28 2003

# Trends in aerosols




***IPCC, 2001***