AEROSOL Particles
What’s all the fuss?

What are they?
Why are they important?
Where do they come from?
How are they measured?
What is AERONET all about?
What is an AEROSOL?

- Liquid or solid particle suspended in the atmosphere
- Size: Typically 0.01 to 20 $\mu$m in diameter
- Composition:
  - Liquid: Water, sulfate, sea salt
  - Solid: BC, WSOC, mineral (dust)
- Shape: Spherical to angular
- Types: Anthropogenic, Natural
Types of Particles
University of Sao Paulo – Institute of Physics

Saharan Dust in the US

Amazon: Biogenic Cluster

Flaming Smoke Smoldering

Smoke Cluster

US Urban Pollution
Effects of Atmospheric Aerosols

- Climate and Weather
  - Short-term: modification of regional precipitation + solar radiation at the surface
  - Long-term: planetary albedo/energy balance

- Human health
  - Increased discomfort, illness + mortality (PNAS study)

- Agricultural impacts
  - Alteration of crop photosynthesis + productivity, changes of monsoon patterns
CO₂ (and water vapor) are main drivers of climate modification.

However, CO₂ is well-mixed, well-understood and it’s effects are relatively easy to model.
GLOabal-Mean Radiative Forcings (RF)

Pre-industrial to present (Intergovernmental Panel on Climate Change, 2007)

<table>
<thead>
<tr>
<th>RF Terms</th>
<th>RF values (W m$^{-2}$)</th>
<th>Spatial scale</th>
<th>LOSU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long-lived greenhouse gases</td>
<td>1.66 [1.49 to 1.83]</td>
<td>Global</td>
<td>High</td>
</tr>
<tr>
<td>CO$_2$</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>N$_2$O</td>
<td>0.48 [0.43 to 0.53]</td>
<td>Global</td>
<td>High</td>
</tr>
<tr>
<td>CH$_4$</td>
<td>0.16 [0.14 to 0.18]</td>
<td>Global</td>
<td>High</td>
</tr>
<tr>
<td>Halocarbons</td>
<td>0.34 [0.31 to 0.37]</td>
<td>Global</td>
<td>High</td>
</tr>
<tr>
<td>Ozone</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Stratospheric</td>
<td>-0.05 [-0.15 to 0.05]</td>
<td>Continental to global</td>
<td>Med</td>
</tr>
<tr>
<td>Tropospheric</td>
<td>0.35 [0.25 to 0.65]</td>
<td>Continental to global</td>
<td>Med</td>
</tr>
<tr>
<td>Stratospheric water vapour from CH$_4$</td>
<td>0.07 [0.02 to 0.12]</td>
<td>Global</td>
<td>Low</td>
</tr>
<tr>
<td>Surface albedo</td>
<td>-0.2 [-0.4 to 0.0]</td>
<td>Local to continental</td>
<td>Med</td>
</tr>
<tr>
<td>Land use</td>
<td>0.1 [0.0 to 0.2]</td>
<td>Continental to global</td>
<td>Med</td>
</tr>
<tr>
<td>Black carbon on snow</td>
<td>-0.7 [-1.8 to -0.3]</td>
<td>Continental to global</td>
<td>Low</td>
</tr>
<tr>
<td>Total Aerosol</td>
<td>-1.2 [-2.4 to -0.6]</td>
<td>Continental to global</td>
<td>Low</td>
</tr>
<tr>
<td>Direct effect</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cloud albedo effect</td>
<td>-0.5 [-0.9 to -0.1]</td>
<td>Continental to global</td>
<td>Med</td>
</tr>
<tr>
<td>Total Natural</td>
<td>0.01 [0.003 to 0.03]</td>
<td>Continental to global</td>
<td>Low</td>
</tr>
<tr>
<td>Solar irradiance</td>
<td>0.12 [0.06 to 0.30]</td>
<td>Global</td>
<td>Low</td>
</tr>
<tr>
<td>Total net anthropogenic</td>
<td>1.6 [0.6 to 2.4]</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Radiative Forcing (W m$^{-2}$)

LOSU denotes level of scientific understanding.

Factor of 4 limits empirical inferences and model evaluation.
Semidirect effects result from increases in atmospheric stability due to heating of the troposphere by absorbing aerosols and reduction of solar flux at the surface, thereby causing clouds to evaporate or suppressing cloud formation.

The most basic forcing is simply that of the modification of net fluxes by scattering and absorption processes, referred to as the direct effect. Such forcing may be defined for the top of the atmosphere or at the surface and is calculated as the difference between net fluxes assessed with and without aerosol loading in the atmosphere.

Indirect effects of aerosols have much greater and include derivative consequences such as changes in cloud optical depth, albedo, and precipitation efficiency (and thus cloud lifetime).

Aerosol Direct, Indirect and ‘Semi-direct’ Effects

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How about a diagram?
Aerosol Direct, Indirect and ‘Semi-direct’ Effects

- Scattering & absorption of radiation
- Unperturbed cloud
- Increased CDNC (constant LWC) (Twomey, 1974)
- Drizzle suppression, increased LWC
- Increased cloud height (Pincus & Baker, 1994)
- Increased cloud lifetime (Albrecht, 1989)
- Heating causes cloud burn-off (Ackerman et al., 2000)

Direct effects:
- Cloud albedo effect/ 1st indirect effect/ Twomey effect
- Cloud lifetime effect/ 2nd indirect effect/ Albrecht effect

Semi-direct effect: Indirect effect on ice clouds and contrails
January 2013: Beijing

PM 2.5 = 900 ug/m3

WHO guidelines: Safe level= 25 ug/m3  (Beijing was 36x higher than this)
January 2013: Beijing

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The dire effects on health should be self-evident

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January 2013: Beijing

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As well as the economic impact

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As well as the economic impact

Do you want to buy this condo?
The Sunny Optimists
Singapore, June 21st, 2013  Air Quality Index (PSI) hits record = 401

Previous record PSI = 226
Also, my family lands at Changi Airport

“All you have to do to smoke in Singapore is open a window”
Singapore, June 21st, 2013   Air Quality Index (PSI) hits record= 401

Previous record PSI= 226

This is not a natural event
What are the sources of aerosol particles?

- **Natural (≈90%)**
  - Volcanoes
  - Dust storms
  - Wildfires
  - Vegetation
  - Sea spray

- **Anthropogenic (≈10% but mostly in N. hemisphere)**
  - Industrial emissions
  - Fossil Fuel combustion
  - Land use/land cover changes
Natural Aerosols

Marine aerosols, wind/wave generated, large particles (>1μm), lowest 100 m, Non absorbing, restricted to oceans, conc. low
Aerosols from Biomass Burning

**Flaming Phase** ⇒ oxygen starved, black carbon, absorbing

**Smoldering Phase** ⇒ oxygen rich combustion, less absorbing
Dust-Natural and Anthropogenic sources
Anthropogenic: Urban Aerosols

Black Carbon (highly absorbing): diesel engines, coal

$\text{SO}_4$ (small, non absorbing): factories, power plants, gas engines
What Does AERONET Provide?

AOD 15 minute observations

AOD Climatology
Anmyon, S. Korea  Monthly Ave. AOD 1999-2002

Size Distributions
Anmyon Island, South Korea  2001 AOD>0.4
Mean of 10 almucantars / AOD level
Spheroid Model Inversions  Sky Error < 7%

Single Scattering Albedo
Anmyon Island, South Korea  2001 AOD>0.4
Mean of 10 almucantars / AOD level
Spheroid Model Inversions  Sky Error < 7%
Aerosols-general characteristics

- Ubiquitous:
  - 5 to 1000 mg/m³

- Remote sensing characteristics
  - Color: \( f(\text{size and composition}) \)
  - Directional Scattering efficiency: \( f(\text{size}) \)
  - Absorption: \( f(\text{composition}) \)

- Lifetime: 5 to 14 days (tropospheric) years (stratospheric)