Positive and Negative Radiative Forcing from Aerosols

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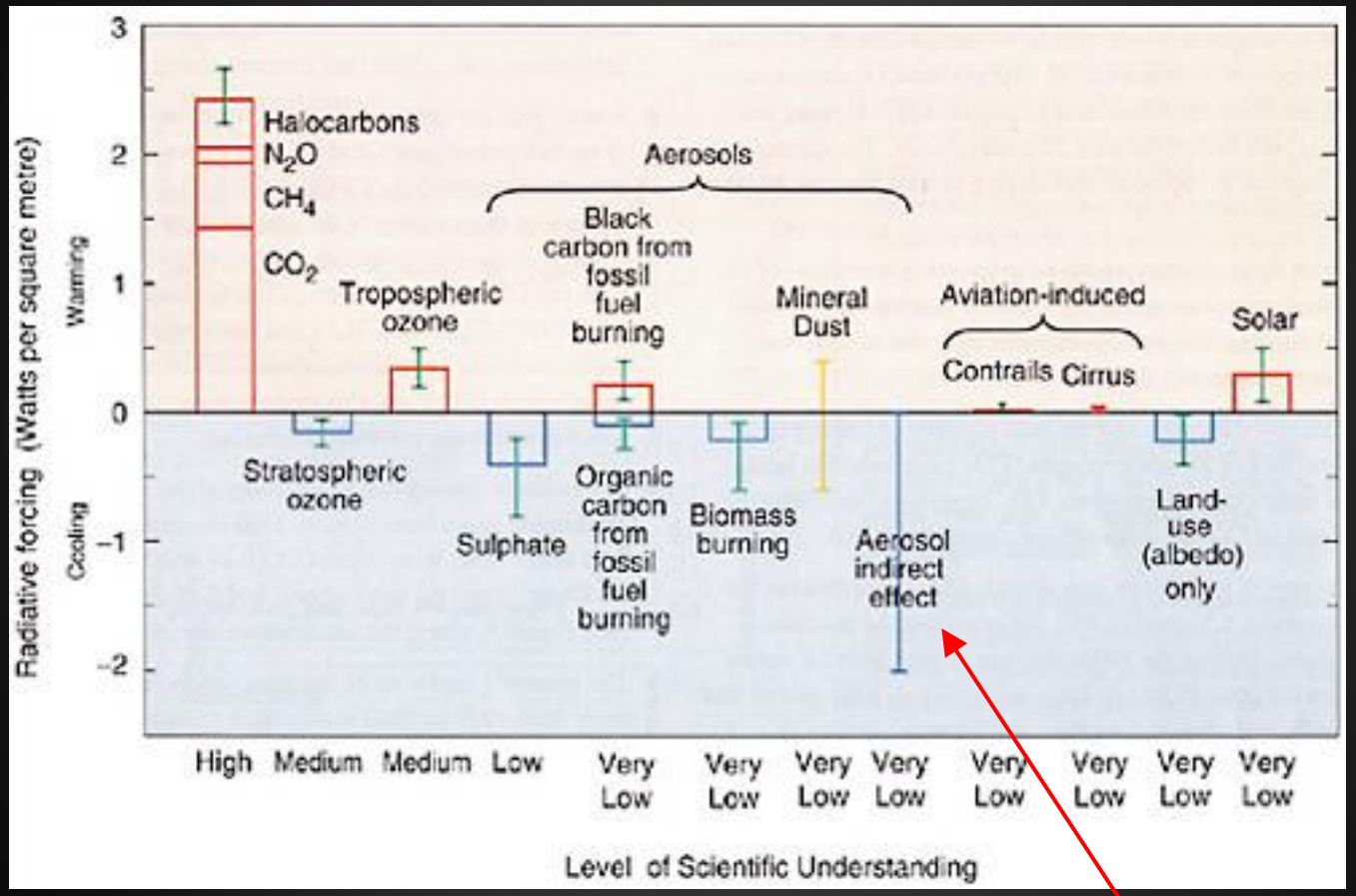
Radiative Forcing

- Quantitatively measure/compare contributions of different agents affecting surface temperature (W/m^2)
- Relevance to policy = global mean temp emphasized in climate change studies
- In reference to climate forcing = energy imbalance imposed on climate system either externally or by human activities

Overview of Climate Forcing

- Changes in:
  - solar energy output
  - volcanic emissions
  - deliberate land modification
  - anthropogenic emissions of greenhouse gases, aerosols, and their precursors.
- Direct radiative forcings
  - directly affect the radiative budget of the Earth
- Indirect radiative forcings
  - create an energy imbalance by altering climate system components, which then lead to changes in radiative fluxes

Contributions Among Radiative Forcing Agents



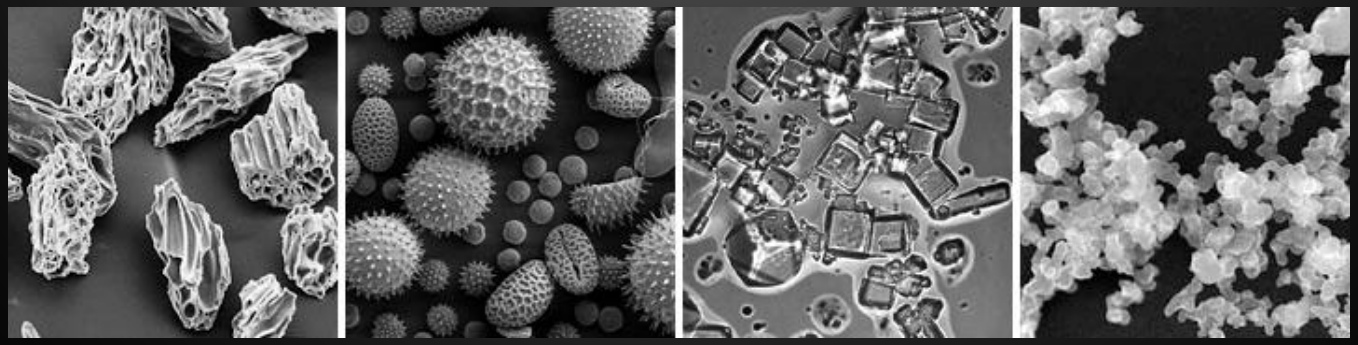
Intergovernmental Panel on Climate Change (IPCC), 2001

=relative extreme uncertainty of understanding of fairly large contributors to changes in average temperature

What is an Aerosol?

Aerosols are minute solid or liquid particles suspended in the atmosphere.

They come in all different sizes, are made of different chemicals and vary in origin.



NASA Earth Observatory, 2010

Sources of Aerosols

- ~90 % by mass have natural origins.
  - Volcanoes- ash, sulfur dioxide and other gases into air, yielding sulfates. Forest fires -partially burned organic carbon.
  - Certain plants -gases + other substances in the air>> aerosols
  - Ocean- some types of microalgae produce dimethylsulfide converted >> sulfates in the atmosphere.
- ~10 % are anthropogenic
  - can dominate the air downwind of urban and industrial areas.
  - Fossil fuel combustion produces large amounts of sulfur dioxide, + water vapor and other gases in the atmosphere >> sulfate aerosols.
  - Biomass burning, a common method of clearing land and consuming farm waste, yields smoke that's comprised mainly of organic carbon and black carbon.

What Do Aerosols Do?

Aerosols interact both directly and indirectly with the earth's radiation budget and climate.

Directly: Aerosols scatter sunlight directly back into space.

Indirectly: Aerosols in lower atmosphere can modify the size of cloud particles, changing how the clouds reflect and absorb sun.

Reddened Sunset caused by Aerosols

Indirect Effect on Climate Via Biogeochemical Feedbacks

- Change in atmos. concentration of CO_2
  - affect fluxes downstream from where they're emitted
  - contribute to change of -.5 (+/- .4) W/m^2
- Effects
  - changing the physical climate of the ocean or land ecosystem, and thereby changing biogeochemical fluxes (climate engineering)
  - depositing chemicals that modify the biogeochemical cycles
  - Warmer temperature= less ability for land and oceans to absorb carbon, so cooling likely allows for more carbon absorption

Three types of Aerosols significantly affecting the Earth's climate.

1 Volcanic Aerosols which form in the stratosphere after major volcanic eruptions.

#2 Desert Dust

#3 Human Made Aerosols

Aerosols in the troposphere

- Comprised of:
  - sea salt and dust caried by wind
  - aerosols formed by chemical transformation from gaseous compounds to molecules that exist in solid or liquid form.

The lifetime of an aerosol in the troposphere is only a few weeks but the sources are strong enough to maintain a significant aerosol burden.

Aerosols contributed by humans have greatly increased in the troposphere, it is currently estimated that the anthropogenic source outweighs the natural sources.

Aerosols in the Stratosphere

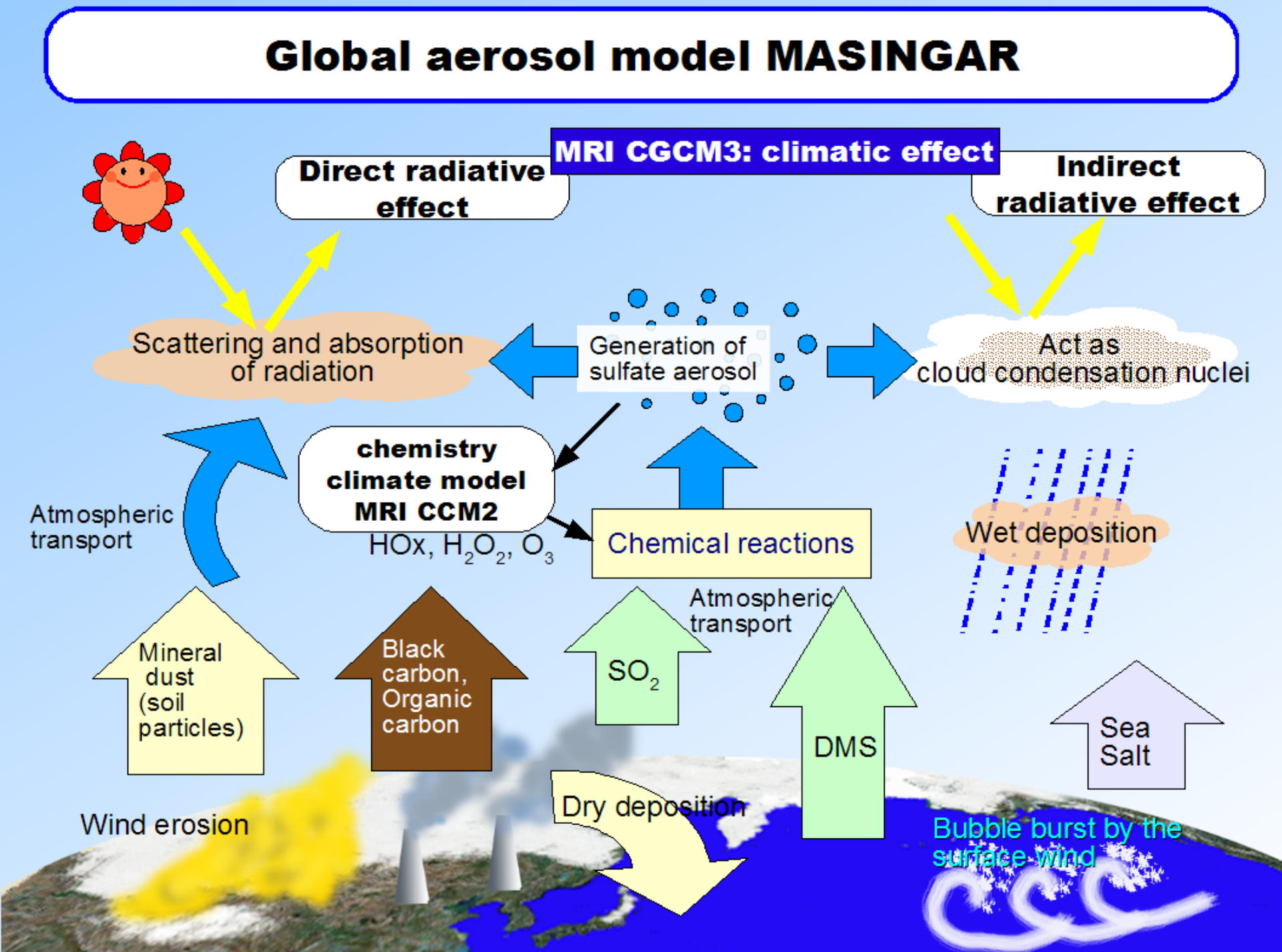
Volcanic eruptions are the major source of aerosols in the stratosphere.

El Chichon eruption in Mexico in 1982 was a small volume eruption of unusually sulfur-enriched magma that produced the first large aerosol veil to be tracked by instruments on satellites.

Global Dimming is something that occurs from stratospheric sulfate aerosols.

El Chichon

Global aerosol model MASINGAR



How do we reduce the effects of aerosols?

Some say we may not want to in some cases...

Natural Reduction

- Most aerosols in the troposphere are naturally removed by cloud formation and precipitation (acid rain)
- Aerosols have a relatively short "lifetime" - a few days to a few weeks
  - - but this process takes longer at the polar regions - why?

Ways to reduce the effects of aerosols

- NOX/SOX controls to reduce acid rain - Clean Air Act
- More efficient combustion to reduce black coal - fuel efficiency
- Alternative, non GHG emitting fuels sources - renewables

Little myth - aerosol hairsprays, Pam, lysol, etc. have not used ozone-depleting substances since the 1970's

Policy Targets and Challenges

- Still large uncertainty of absolute effects
  - Knowledge of direct radiative forcing of aerosols is limited to a large extent by uncertainty about the global distributions and mixing states of aerosols
  - Removal of aerosols from the atmosphere occurs mainly by wet deposition, but model parameterizations of this process are highly uncertain and rudimentary in their coupling to the hydrological cycle
- Costly intervention

Projected Costs and the quantified effects from effects of aerosols fdk

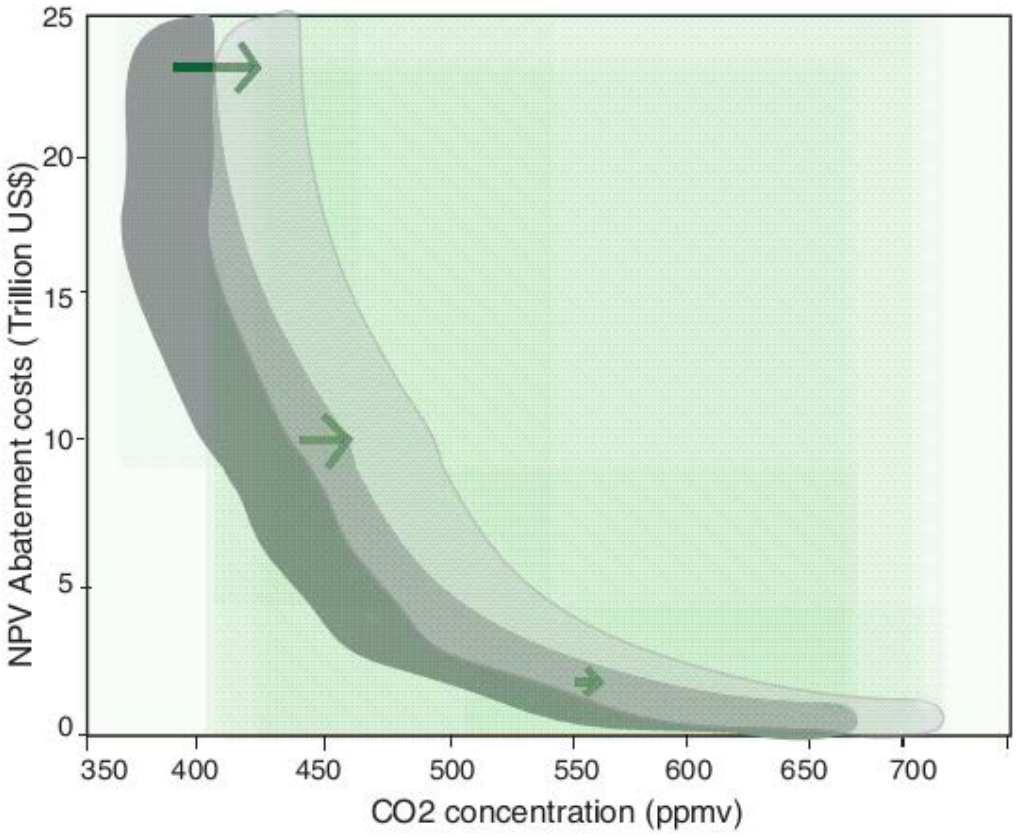


Fig. 2. Net present value (NPV) of abatement costs for different 2100 CO_2 values, based on the range presented in (*36*) (dark gray outline) and shifted by aerosol indirect effect on biogeochemical cycles (green arrows and light gray outline). For each concentration level, the values are shifted by the aerosol indirect effect on biogeochemical cycles, assuming that this effect is equivalent to −30 ppm of CO_2 today (as derived in the text as a range between 7 and 50 ppm) and decreasing this effect as the estimated aerosol radiative forcing decreases in the representative concentration pathways estimated for the next Intergovernmental Panel on Climate Change assessment report (*8*, *36*–*42*).

Additional Sources of Info

- James Hansen, climate change guru
  - http://www.columbia.edu/~jeh1/mailings/2011/20110415_EnergyImbalancePaper.pdf
- NASA / NASA Earth Observatory
  - http://earthobservatory.nasa.gov/Features/Aerosols/page1.php
  - http://www.nasa.gov/centers/langley/news/factsheets/Aerosols.html
- *Science* on biogeochemical component
  - http://www.sciencemag.org/content/334/6057/794.full.pdf
  - for calculations: http://www.sciencemag.org/content/suppl/2011/11/10/334.6057.794.DC1/Mahowald.SOM.pdf

Exam Questions

1. Describe the effects of aerosols in both the lower and upper atmospheres.
2. How do aerosols contribute to the ozone hole that is formed in polar regions during the winter months?
3. Explain why the net effect of aerosols in the atmosphere is a cooling effect. What are the implications of this for climate change policy?
4. Name 2 anthropogenic and 2 natural sources of aerosols in the atmosphere.