Lecture 2.

The main processes in the climate system involving aerosols and clouds: introductory survey.

Outline:

1. What are climate and the climate system? Some definitions.
2. *Discussion topics*: What are the main processes in the climate system involving aerosols and clouds? What are spatial and temporal scales of these processes? What are the most outstanding problems?
3. Lecture summary: emerging issues

Required reading: Climate Change 2001: The Scientific Basis, IPCC 2001. Chapter 1. The climate system an overview.

http://www.grida.no/climate/ipcc_tar/wg1/index.htm

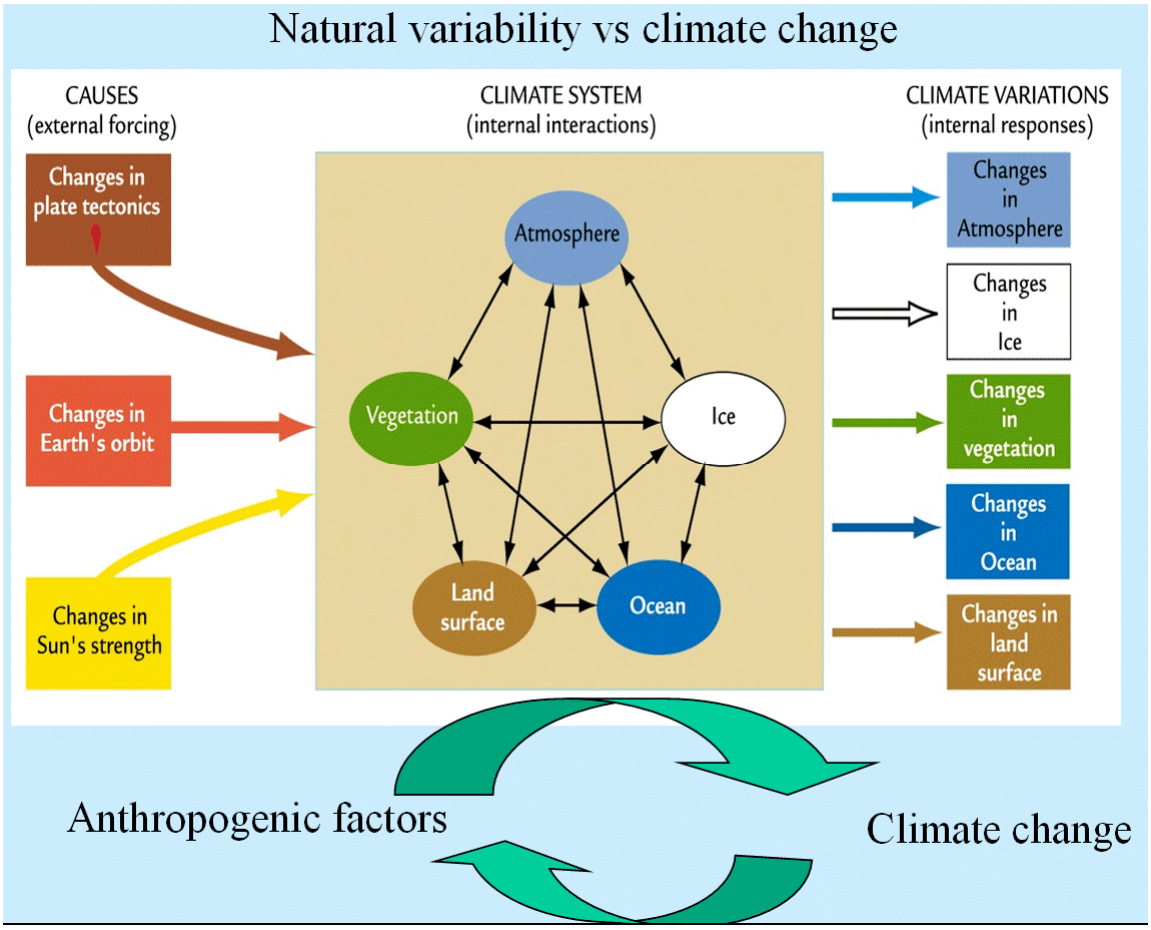
Assignment: *Name and be ready to discuss in class one or several important processes in which aerosols and/or clouds can affect the workings of the climate system. Identify the characteristic scales of these processes and the potential challenges in quantifying them. Prepare one-two pages for discussion in class. Email your pages to me (isokolik@eas.gatech.edu) by Jan.21th.*

1. What are climate and the climate system?

- Climate is the average state of the environment at a given time and location. This includes the mean values of a range of variables (temperature, pressure, wind, precipitation, cloudiness, etc.) - *what is the time period?*
- The components of the climate system are: atmosphere, ocean, land, cryosphere, and biosphere (including humans). The study of climate is a quantitative science, involving the understanding of the transfer of energy (and matter: gases and particulates) from the sun to the earth, from the earth to the space, and between the components of the climate system (atmosphere-land-ocean- cryosphere-

biosphere), all under fundamental physical laws (such as conservation of mass, heat, and momentum)

- Climate is continually changing due to external and internal influences (key problem: natural variability vs. climate change)



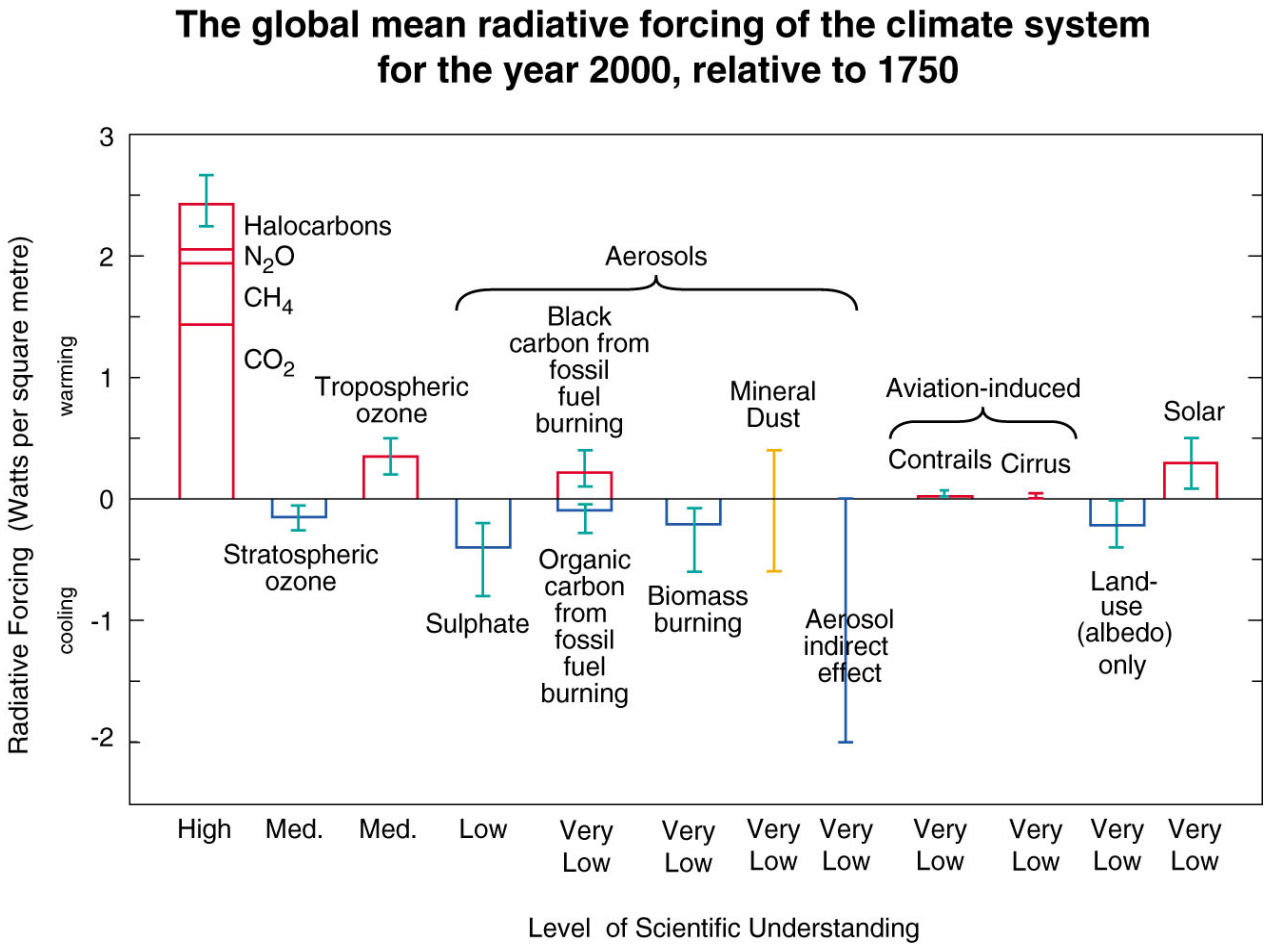
What is forcing?

Common meaning: *forcing = impact*

IPCC definition: the term *radiative forcing* means as a change of net radiative flux at the top of the atmosphere (TOA) caused by a radiatively active driver (i.e., due to the change of amount/properties of anthropogenic aerosol and clouds).

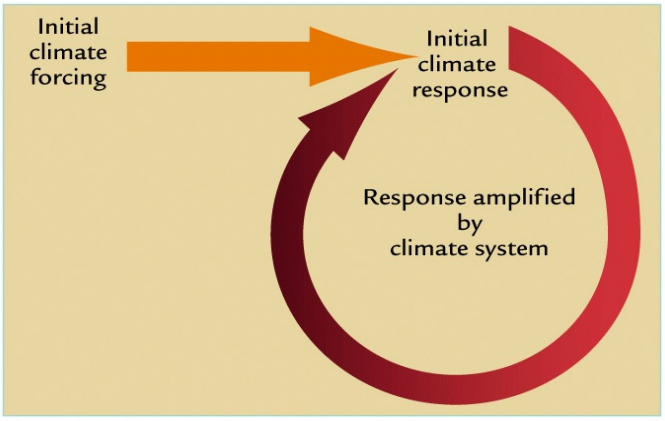
Direct radiative forcing of aerosols: aerosols interact with atmospheric radiation resulting in the change of the Earth's energy balance.

Indirect radiative forcing (via clouds): aerosols change clouds => changes in clouds result in the change of the Earth's energy balance.

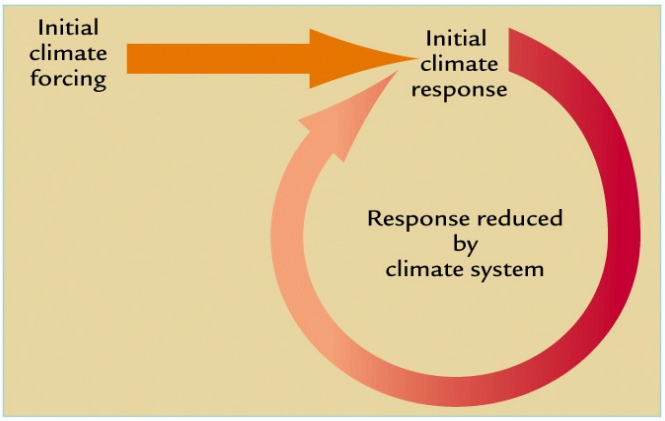


What is feedback?

Feedback is a process that alters the initial climate change either by amplifying them (positive feedbacks) or by suppressing them (negative feedbacks).



A Positive feedback



B Negative feedback

2. *Discussion topics*: What are the main processes in the climate system involving aerosols and clouds? What are spatial and temporal scales of these processes? What are the most outstanding problems?

Discussion materials (assignment for Lecture 2) are posted at course web.

3. Lecture summary: emerging issues

The role of aerosols/clouds in planetary energy balance:

1) In equilibrium, TOA energy balance (absorbed solar energy equals emitted thermal infrared IR) radiation) determines the state of the climate system.

2) Absorbed solar energy depends on solar constant (intensity of Sun at Earth's distance) and planetary albedo (fraction of incident sunlight reflected). Aerosols and clouds are the key factors controlling the planetary albedo (other factors are gaseous (Rayleigh) scattering and the surface reflectivity).

3) Emitted IR radiation depends on the surface temperature, atmospheric temperature, the concentration of greenhouse gases and the presence of aerosols and clouds.

4) Climate change occurs when one or both sides of energy balance are perturbed.

   Example 1: Increase greenhouse gases -> decrease IR radiation to space -> absorbed solar exceeds emitted thermal -> temperature must increase to restore balance.

   Example 2: Increase planetary albedo -> decrease absorbed solar -> emitted thermal exceeds absorbed solar -> temperature must decrease to restore balance.

Existing complexity in determining the radiative impacts of aerosols and clouds stems from their complex nature (e.g., varying composition, size, shape, concentration, mixing state, distinct regional features and short lifetime (~ one-two weeks), etc.)

Some emerging issues:

- ✓ IPCC(2001) considers only TOA radiative forcing – *other impacts*?
- ✓ IPCC(2001) considers only sulfates, BC and OC from fossil fuel burning, biomass burning aerosols, and dust – *are there other types of aerosols that can affect climate*? *What about multi-component aerosol particles?*

- ✓ Does IPCC(2001) indirect radiative forcing cover all important effects of aerosols on clouds?
- ✓ IPCC(2001) considers direct and indirect radiative impacts – *feedbacks*?
- ✓ IPCC(2001) assessments are mainly based on GCM results – *how reliable GCM treatments of aerosols and clouds?*
- ✓ IPCC(2001) assessments are mainly based on GCM results – *observational evidence*?