Climate Variability and Climate Change

1. Definitions
   - The Climate System; Natural and Forced Variability
2. Natural Variability
   - North Atlantic Oscillation, El Nino/Southern Oscillation
3. Forced Change (natural)
   - Volcanic Eruptions (scattering particles)
   - Changes in the Solar Luminosity
4. Forced Change (human)
   - Burning of fossil fuels (increasing GH gases)
   - Burning of biomass (scattering particles)

Agents of Climate Change: Forcing

Climate can change due to external forcing

- **Natural Forcing**
  - Examples:
    - Volcanoes (scattering particles $\alpha$)
    - Changes in the Earth’s orbit
    - Changes in the solar luminosity ($S_0$)

- **Human Forcing**
  - Examples:
    - Emissions of greenhouse gases ($\xi$)
    - Aerosols (tiny particles $\gamma$)
    - Land use changed (albedo $\alpha$, etc.)
“Radiative Forcing”

**Radiative Forcing (RF)** is a measure of the change in the energy balance of the Earth-atmosphere system when factor(s) that affect climate are altered. (IPCC ’07)
- The RF is calculated instantaneously to the alteration (i.e., before the atmosphere adjusts to the change)
- Called ‘radiative’ because the process that communicates the net change in energy is electromagnetic radiation

A positive Radiative Forcing results in a net increase in downward energy and thus will lead to a warming of the surface. Examples of RF:
- Increase in the solar luminosity
- Increase in greenhouse gas concentration

RF allows one to assess and compare the relative importance of different natural and human-induced forcings on climate

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### 2. Examples of Natural Variability

**The North Atlantic Oscillation (NAO)**
(year to year variations in the wintertime storminess in the N. Atlantic)

![North Atlantic Oscillation](image)

**El Nino/Southern Oscillation (ENSO)**

- El Nino/Southern Oscillation (ENSO) is the dominant pattern of climate variability on year-to-year time scales
- The physics responsible for ENSO are localized in the tropical Pacific, but ENSO causes global climate anomalies
ENSO

Changes in the distribution of sea surface temperature are coordinated with changes in atmospheric circulation and rainfall patterns;

Color maps show local correlation with Nino3.4 -- a good index of the state of ENSO.