ES200/ES250

Module: Global Environmental Change

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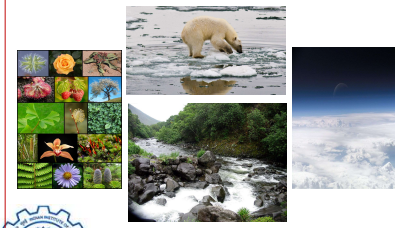
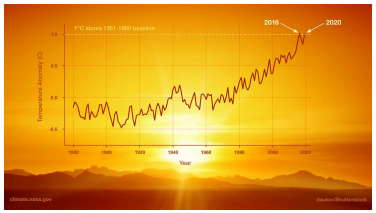
Module Objectives

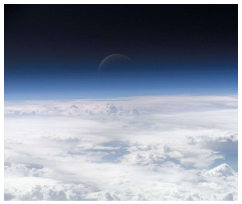
1) Environmental change and planetary boundaries



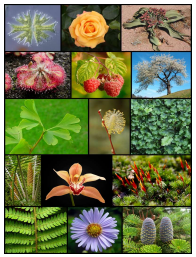
2) Global Climate Change

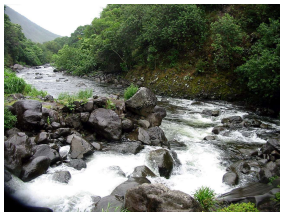


Environment



- Biotic and abiotic components surrounding an organism or a population, thus influencing their survival, development and evolution.
- Vary from microscopic to global scale
- Environmental science = systematic study of human interactions with the environment





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What is Environmental Change?

- Change or disturbance of the environment by either natural causes, anthropogenic factors, or even animal-environment interactions.
- Environmental degradation refers to the *"reduction of the capacity of the environment to meet social and ecological objectives, and needs"*
  - Depletion of resources
  - Reduced environmental quality
  - Habitat change

More information: http://www.unisdr.org/eng/library/lib-terminology-eng%20home.htm

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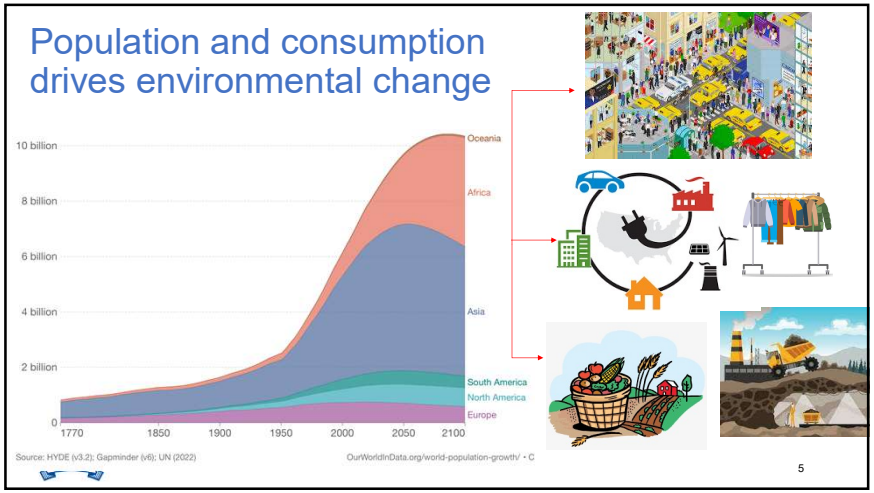
Population and consumption drives environmental change



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Planetary boundaries

- Planetary boundary representative of a “safe operating space for humanity”
  - Transgressing such a boundary has a deleterious or catastrophic risk to human and ecosystem health
  - Such change likely to be irreversible, non-linear and result in regional to planetary scale impacts

More information: https://www.stockholmresilience.org/research/planetary-boundaries.html

Podcast: https://open.spotify.com/episode/69JCjeqnXpwkvKZmdI7Ol6?si=9588e8645b4f4b8a

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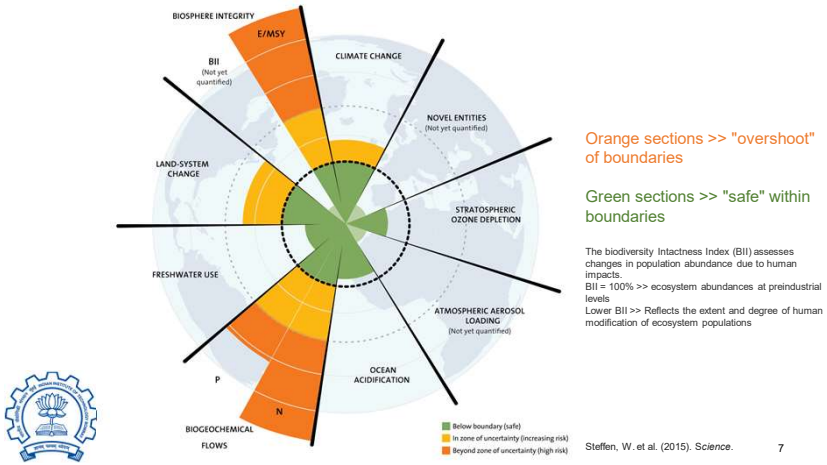

Orange sections >> "overshoot" of boundaries

Green sections >> "safe" within boundaries

The biodiversity Intactness Index (BII) assesses changes in population abundance due to human impacts.
BII = 100% >> ecosystem abundances at preindustrial levels
Lower BII >> Reflects the extent and degree of human modification of ecosystem populations

Steffen, W. et al. (2015). *Science*.

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Nine boundaries: some exceeded, some at risk

1) Climate change
2) Biodiversity loss
3) Biogeochemical flows of nitrogen and phosphorus
4) Land-system change
5) Ocean acidification
6) Stratospheric ozone depletion
7) Atmospheric aerosol pollution
8) Freshwater use
9) Release of novel chemicals

Humanity already exists outside the safe operating space for at least four of the nine boundaries

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2) Loss of Biosphere Integrity

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2) Loss of Biosphere Integrity

- Problem: Ecosystem changes due to human activities more rapid in the past 50 years than at any time in human history (The Millennium Ecosystem Assessment of 2005)
  - Increasing the risks of abrupt and irreversible changes in terms of biodiversity loss and extinctions.
- Main drivers: Demand for food, water, and natural resources.
- Solutions: Current high rates of ecosystem damage and extinction can be slowed by efforts to protect the integrity of living systems, enhance habitat, and improve connectivity between ecosystems while maintaining high agricultural productivity.

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3) Biogeochemical Flows

- Problem: Anthropogenic inputs of nitrogen and phosphorous for agricultural production, from mining and through smaller utilities such as detergent use.
  - Release and accumulation of reactive nitrogen (Nr includes NH_3, N_2O, NO_x, and nitrates) and phosphorous in water, air, and soil.
  - Reactive nitrogen has local, regional and global scale impacts.
- Main drivers: Demand for food, fuel, and fibre.
- Solutions: Reduced reliance on N and P inputs by shifting farming practices and consumer demands of food and fuel. End-of-life treatment to reduce Nr and P discharge to air and water.

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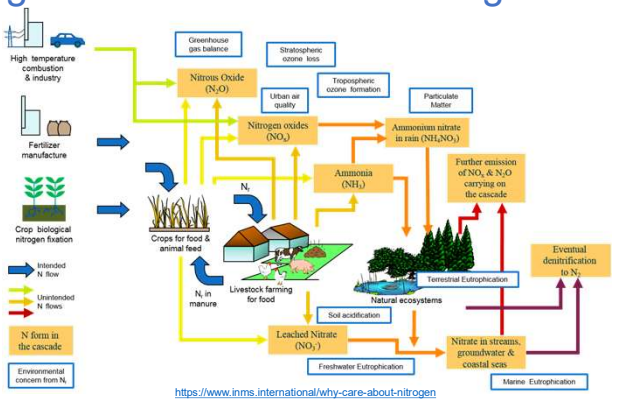
3) Biogeochemical Flows of Nitrogen



https://www.inms.international/why-care-about-nitrogen

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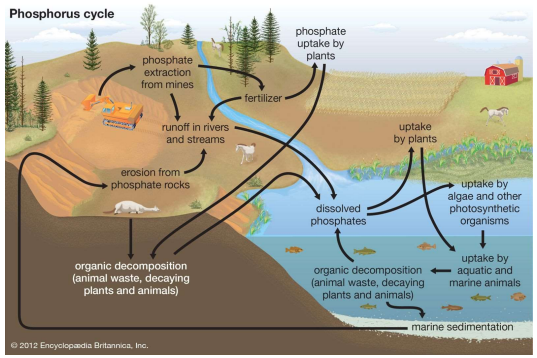
3) Biogeochemical Flows of Phosphorous



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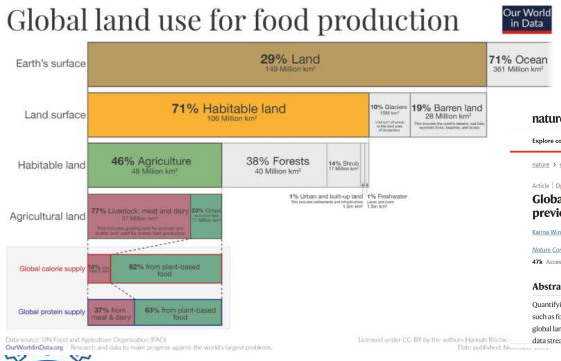
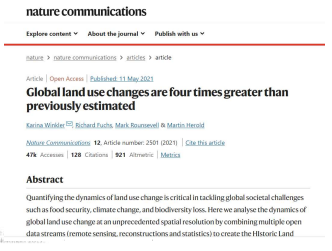
4) Land-system change

Land use change accelerated between 1960-2005, and has since slowed down





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4) Land-system change

- Problem: Widespread conversion of forests, grasslands, wetlands and other vegetation types to agricultural land and for mining and logging.
- Main drivers: Demand for food (crops, grazing land, feed), biofuel, and natural resources (wood for paper products, precious metals, sand, etc.)
- Solutions: Afforestation, greener agricultural practices, reduced illegal mining and logging, and product and process improvement.

- Explore deforestation patterns and drivers: https://www.globalforestwatch.org

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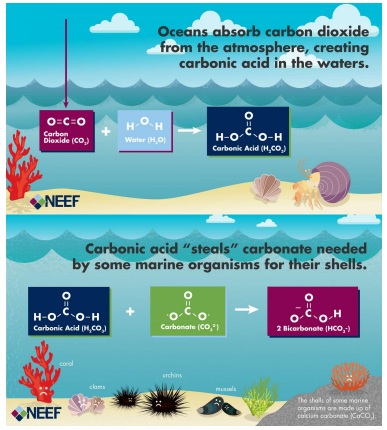
5) Ocean Acidification

- Problem: Quarter of emitted CO_2 dissolved in oceans >> reduces pH and alters biochemistry >> impacts shell and skeleton formation.
  - Ocean acidity has increased by 30% since pre-industrial times.
- Main drivers: Fossil fuel combustion
- Solutions: Climate change action, reduced dumping of illegal waste



https://news-oceanacidification-icc.org/2018/08/10/marine-life-and-ocean-acidity/

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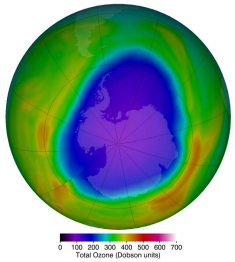
6) Stratospheric Ozone Depletion

- Problem: Release of ozone-depleting substances that breakdown the protective stratospheric ozone layer >> increased cancer risk
- Main drivers: Release of ODS such as chlorofluorocarbons, halons, hydrochlorofluorocarbons that are present in solvents, refrigerants, degreasing agents, propellants, fire extinguishers and as agricultural pesticides.
- Solutions: Montreal Protocol helped reduce ODS!
- NASA ozone watch: https://ozonewatch.gsfc.nasa.gov/

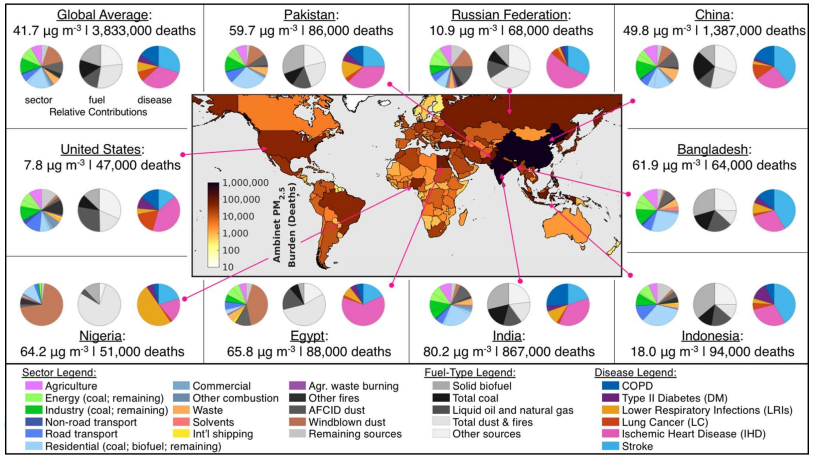


Antarctic ozone hole occurs annually in September and October (Spring). Purples and deep blues indicate low ozone levels.
Credit: NASA's Goddard Space Flight Center.

7) Atmospheric Aerosols

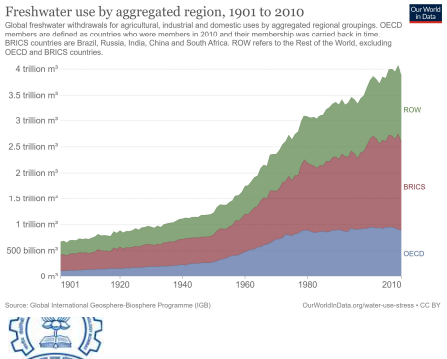
- Problem: Aerosols or particulate matter (PM_{10} and $PM_{2.5}$, PM with diameters ≤ 10 and 2.5 μm respectively) emitted
- Main drivers: Industry, power generation, transportation, road dust, cookstoves, mining, construction, agriculture, and waste burning.
- Solutions: Low-carbon, clean and energy-efficient technologies, and improved waste management.

- Satellite $PM_{2.5}$ data: https://sedac.ciesin.columbia.edu/data/set/sdei-global-annual-gwr-pm2-5-modis-misr-seawifs-aod-v4-gl-03



McDuffie, Erin E., et al. "Source sector and fuel contributions to ambient PM2.5 and attributable mortality across multiple spatial scales." Nature communications 12.1 (2021)

8) Freshwater Use



- Problem: Human demand for freshwater has altered the functioning and distribution of global freshwater systems impacting the hydrological system.
  - Half-billion people are subject to water stress.
  - Changes in precipitation, soil acidification, habitat degradation, and crop yield impacts.
- Main drivers: Freshwater withdrawals for agriculture, industry and municipal uses have increased nearly six-fold since 1900.
- Solutions: Water-efficient technologies, water boundaries for consumptive freshwater use.

9) Release of Novel Chemicals

- Problem: Emissions of toxic and long-lived substances such as synthetic organic pollutants, heavy metal compounds, and radioactive materials have potentially irreversible impacts on health and the environment.
  - Reduced fertility, genetic damage, and bioaccumulation through the food chain.
- Main drivers: Demand for fuel, precious metals, pharmaceuticals, and agrochemicals.
- Solutions: Reduced demand for novel chemicals, redesign of products and processes, environmental labels.

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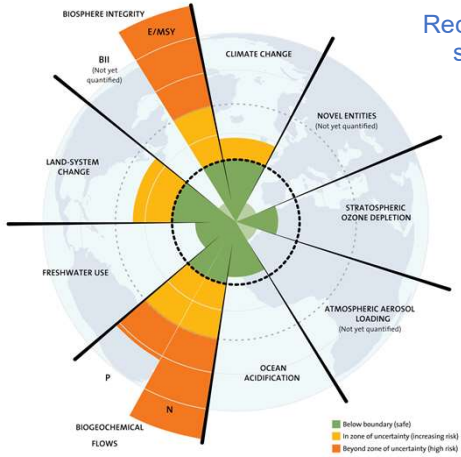

Recap: Nine planetary boundaries, some exceeded, some at risk

1) Climate change
2) Biodiversity loss
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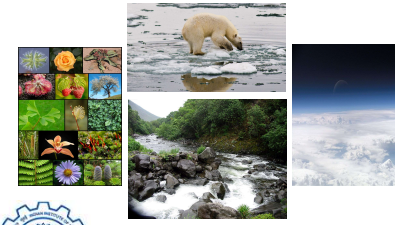
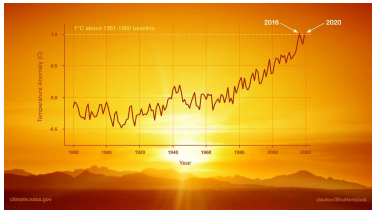


2) Global Climate Change



Is Climate changing?: Weather versus climate

- Weather >> short-term conditions of the lower atmosphere, such as precipitation, temperature, humidity, and wind.
- Climate >> long-term atmospheric change, usually defined as 30 years or more.

Weather-climate interlinked >> changing climate can impact short-term weather patterns

Is the climate changing? Is the change anthropogenic?

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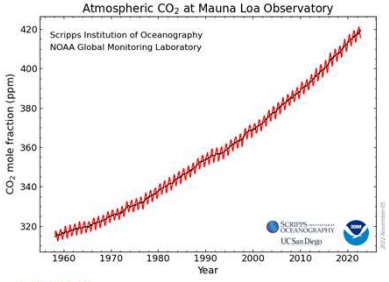
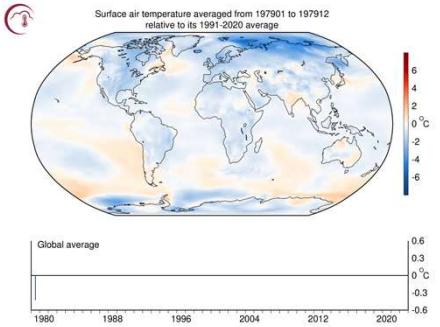
Atmospheric Trends in a Changing Climate

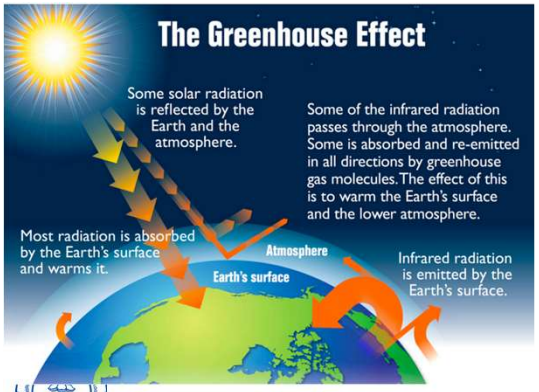
CO_2 in October 2022: 415.7 ppm



https://gml.noaa.gov/ccgg/trends/



https://climate.copernicus.eu/temperature-animations



https://onetreeplanted.org/blogs/stories/difference-global-warming-climate-change

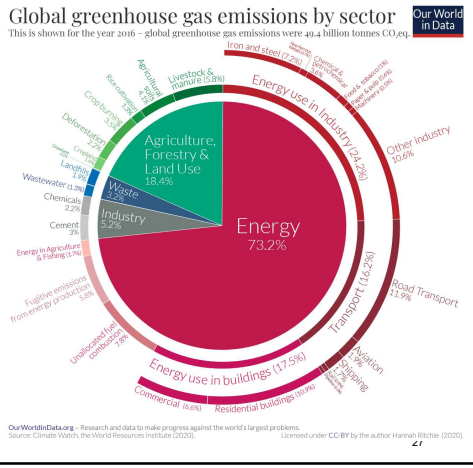
- Global warming refers to a steady rise in global temperatures as a result of the greenhouse effect.
- Climate change is the long-term change in the weather due to greenhouse gases.
  - Net result of the interaction of GHGs and aerosols with the radiative balance >> net warming.
  - Some regions could get colder due to climate change!

Greenhouse gas (GHG): Gas that absorbs and emits radiant energy within the thermal infrared range, causing the greenhouse effect.

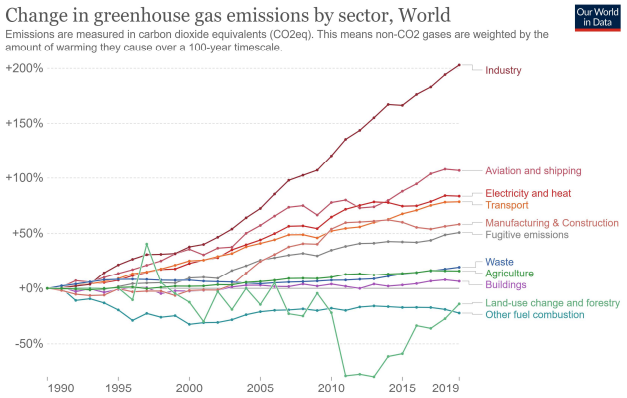
Global warming potential (GWP): measure of how much energy emissions of 1 ton of a gas will absorb over a given period of time, relative to emissions of 1 ton of carbon dioxide (CO_2).

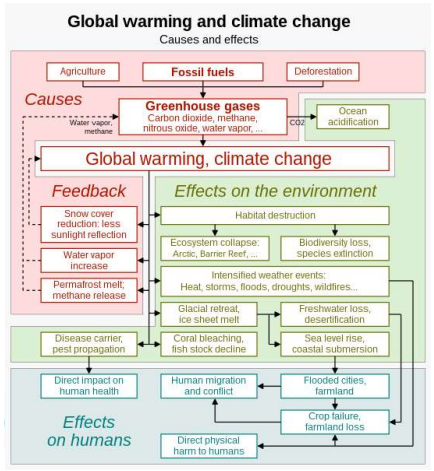
GHG	GWP for 100 years
CO_2	1
CH_4	23
N_2O	296
HFC - 23	12 000
HFC – 134a	1 300
SF_6	22 200

Source: *IPCC Third Assessment Report* (2001).



Global demand for energy, transportation, and industrial products is the key driver of GHG emissions

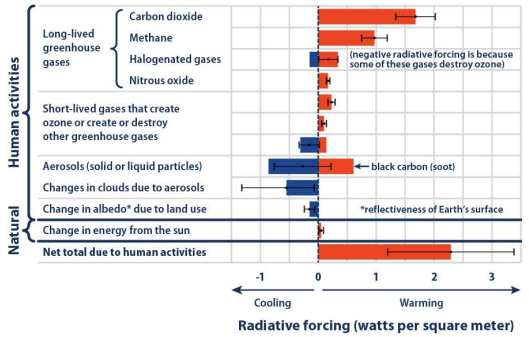




Climate System

- Five interacting components: Atmosphere, hydrosphere, cryosphere, lithosphere, biosphere.
- Forcing: measures the imbalance in the Earth's energy budget caused by a perturbation of the climate system (eg: GHG emissions).
- Feedback: processes that amplify or reduce the effects of climate forcing. Positive forcing increases temperature; negative forcing reduces the temperature.

Radiative Forcing Caused by Human Activities Since 1750

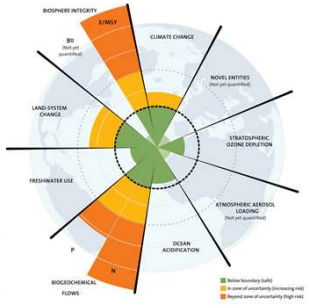


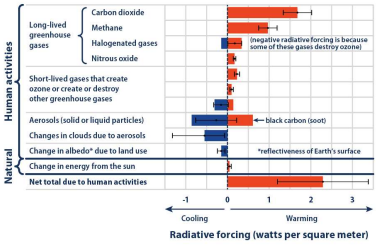
https://www.epa.gov/climate-indicators/climate-change-indicators-climate-forcing

Mitigating Climate Change is a Multi-Sector Challenge

Recap:

1) Global environmental change is largely driven by anthropogenic activities
2) Impacts are multi-fold as shown through nine interconnected planetary boundaries
3) Climate change refers to long-term changes in the weather and is largely attributed to emissions of greenhouse gases.





Recommended resources

Textbook:

- Ela, Wendell, and Masters, Gilbert M.. Introduction to Environmental Engineering and Science. United Kingdom, Prentice Hall, 2008.
- IPCC Fifth Assessment Report: https://www.ipcc.ch/assessment-report/ar5/

Publications:

- Johnson, D.L., Ambrose, S.H., Bassett, T.J., Bowen, M.L., Crummey, D.E., Isaacson, J.S., Johnson, D.N., Lamb, P., Saul, M. and Winter-Nelson, A.E., 1997. Meanings of environmental terms. *Journal of environmental quality*, *26*(3), pp.581-589.
- Steffen, W., Richardson, K., Rockström, J., Cornell, S.E., Fetzer, I., Bennett, E.M., Biggs, R., Carpenter, S.R., De Vries, W., De Wit, C.A. and Folke, C., 2015. Planetary boundaries: Guiding human development on a changing planet. *Science*, *347*(6223), p.1259855.

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Explore trends in Global Environmental Change

Global environmental change is an expansive, interdisciplinary subject. Multiple institutional repositories help provide insight into the ever-changing world around us. Select datasets are listed here. Explore these datasets and make at least three observations:

- Global Forest Watch: https://www.globalforestwatch.org/map/
- GHG from Energy Use: https://www.iea.org/data-and-statistics/data-tools/greenhouse-gas-emissions-from-energy-data-explorer
- Agriculture and Environment: https://www.fao.org/faostat/en/#data >> Select “climate”
- Climate Interactive Viewer: https://climate.nasa.gov/explore/interactives
- Food and footprints: https://www.bbc.com/news/science-environment-46459714

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Thank you!

- ES200/ES250 related queries: Email the faculty in charge
- Queries related to this module: Email Professor Srinidhi Balasubramanian at srinidhi@iitb.ac.in with the subject line “Online ES200/ES250 Query”

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