Oct 22: Carbon Cycle and Climate Change

Update:

- Results from the Midterm Exam and D2L update
- Field Excursion on Oct 27 to Gustafson Farm
- Overview of the Remaining Topics
- Carbon stories on 19/29, instead of UHI

Foci of the Day

- Global carbon budget
- Human dimension and policy

Reading (reference)

Executive summary (Pages 968-969) of

Friedlingstein, P., O'sullivan, M., Jones, M. W., Andrew, R. M., Hauck, J., Landschützer, P., ... & Zeng, J. (2024). Global carbon budget 2024. *Earth System Science Data Discussions*, *2024*, 1-133.

Midterm Exam

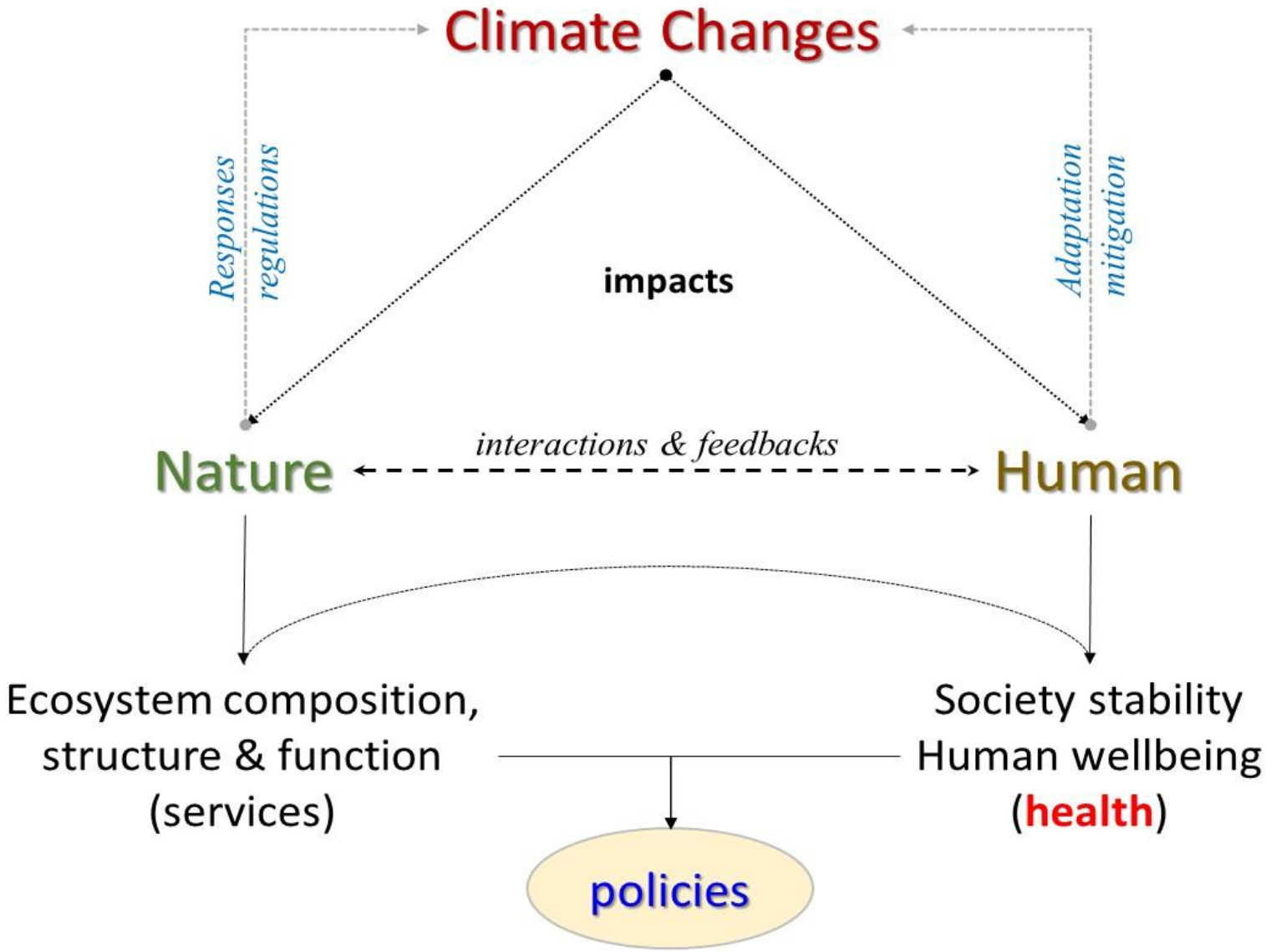
- Average: 100.61
- Min: 95
- Max: 105

- 100 points will be awarded if your score exceeded 100
- Multiple choices?

Schedule: remaining topics

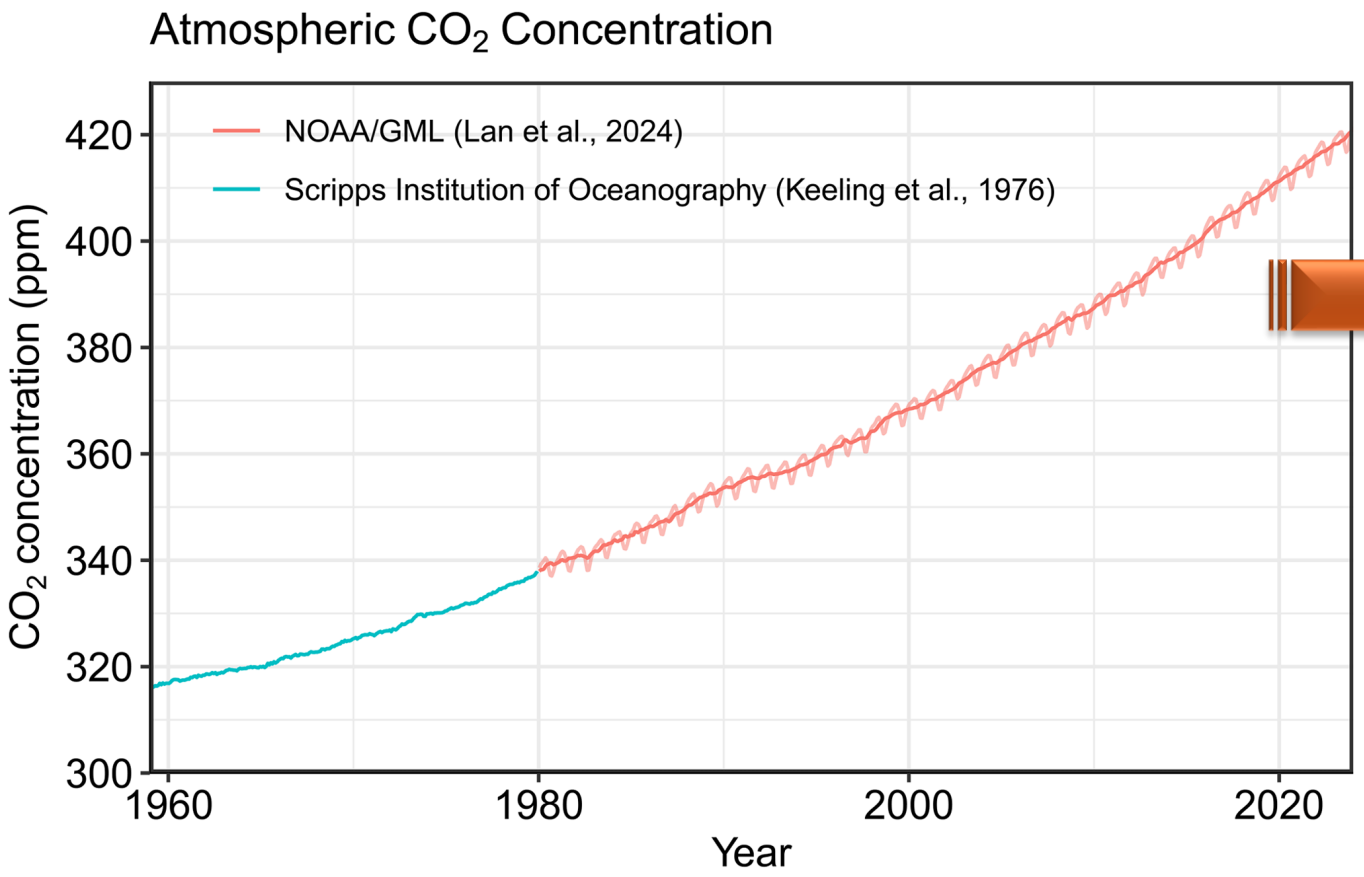
- Carbon Cycle and Climate Change (10/22, 10/29)
- Urban Heat Islands (UHI) (11/3)
- Sea Level Rises (11/5)
- Coral Reef & Ocean Bleaching
- ENSO (El Niño, La Niña, Neutral Phases)
- Climate Extremes (heatwaves, drought, etc.)
- Glacier Melting
- Public Health & Human Migration
- Society and Policy (Dr. Tom Diez)

Climate-Ecosystem-People Feedback



Global Carbon Budget

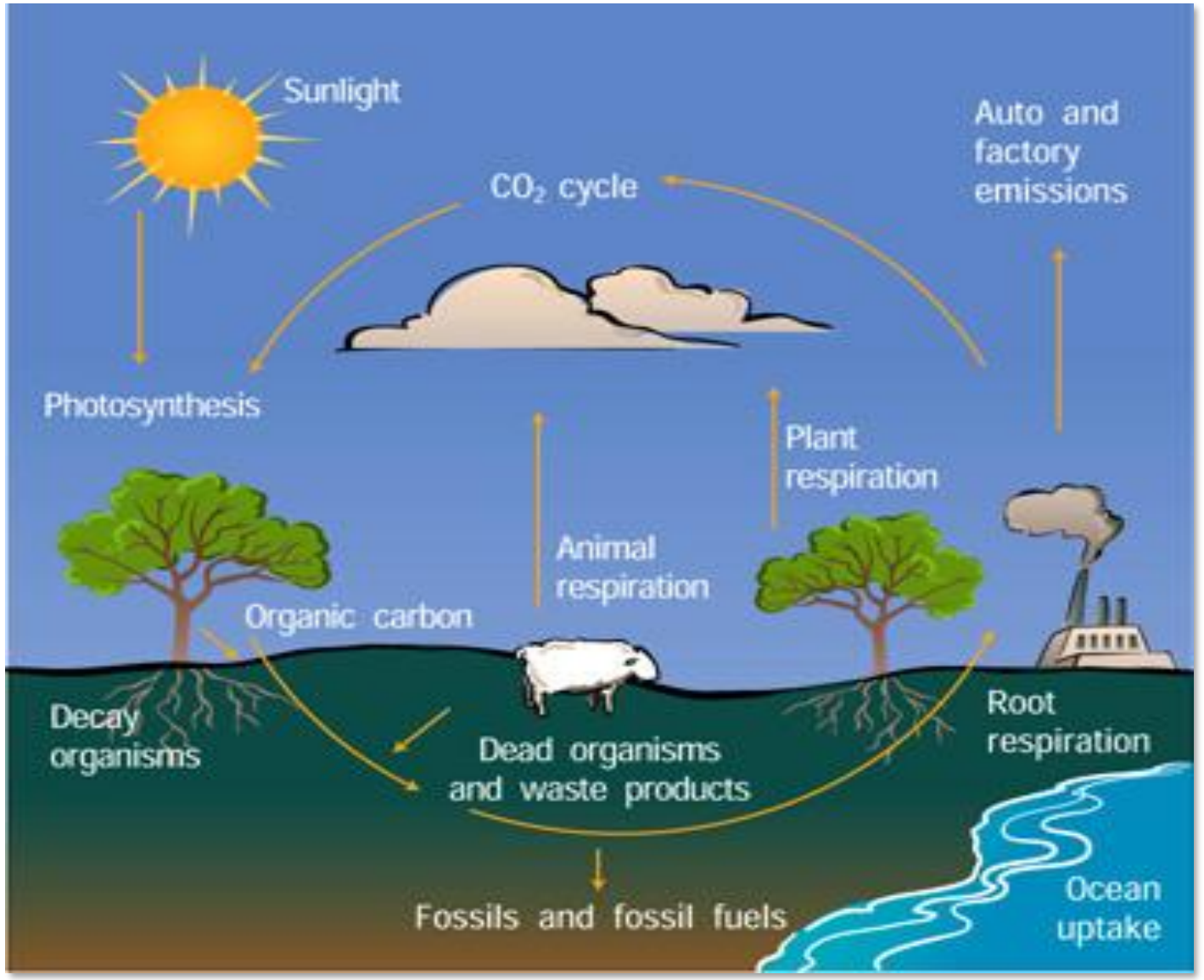
Surface average atmospheric CO_2 concentration (ppm) since 1960



Increase in global temperature through greenhouse effects

Friedlingstein et al. 2024

Global Carbon Cycle



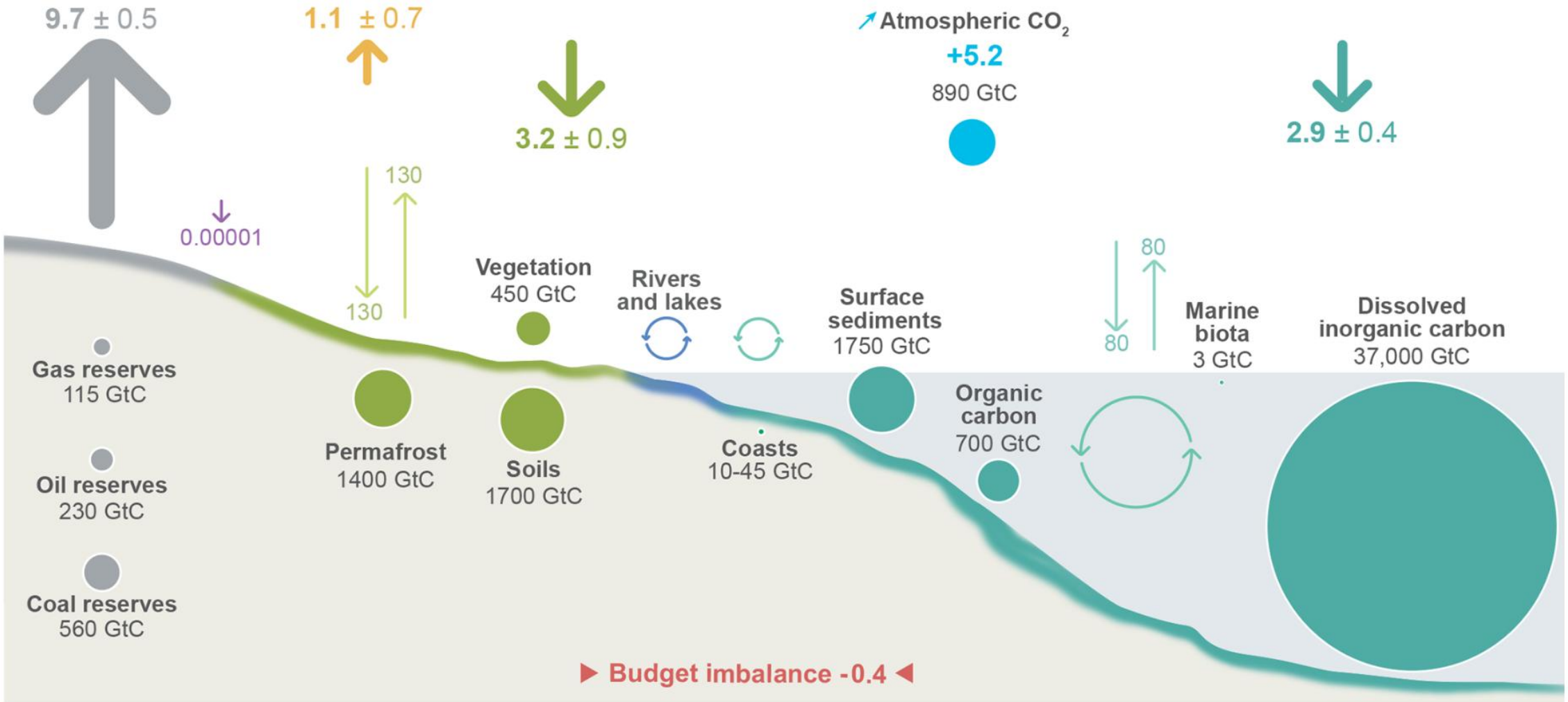
independent estimates (1) to (5) above do not necessarily add up to zero. We hence estimate a budget imbalance (B_{IM}), which is a measure of the mismatch between the estimated emissions and the estimated changes in the atmosphere, land, and ocean, as follows:

$$B_{IM} = E_{FOS} + E_{LUC} - (G_{ATM} + S_{OCEAN} + S_{LAND}). \quad (1)$$

G_{ATM} is usually reported in ppm yr^{-1}, which we convert to units of carbon mass per year, GtC yr^{-1}, using 1 ppm = 2.124 GtC (Ballantyne et al., 2012; Table 1). Units of gigatonnes of CO_2 (or billion tonnes of CO_2) used in policy are equal to 3.664 multiplied by the value in units of gigatonnes of carbon (GtC).

- Fossil CO_2 emissions (E_{FOS})
- CO_2 emissions from land-use, land-use change, and forestry (E_{LUC})
- CO_2 removal (CDR) not based on vegetation
- Growth rate in atmospheric CO_2 concentration (G_{ATM})
- Ocean CO_2 sink (S_{OCEAN})
- Land CO_2 sink (S_{LAND})

The global carbon cycle



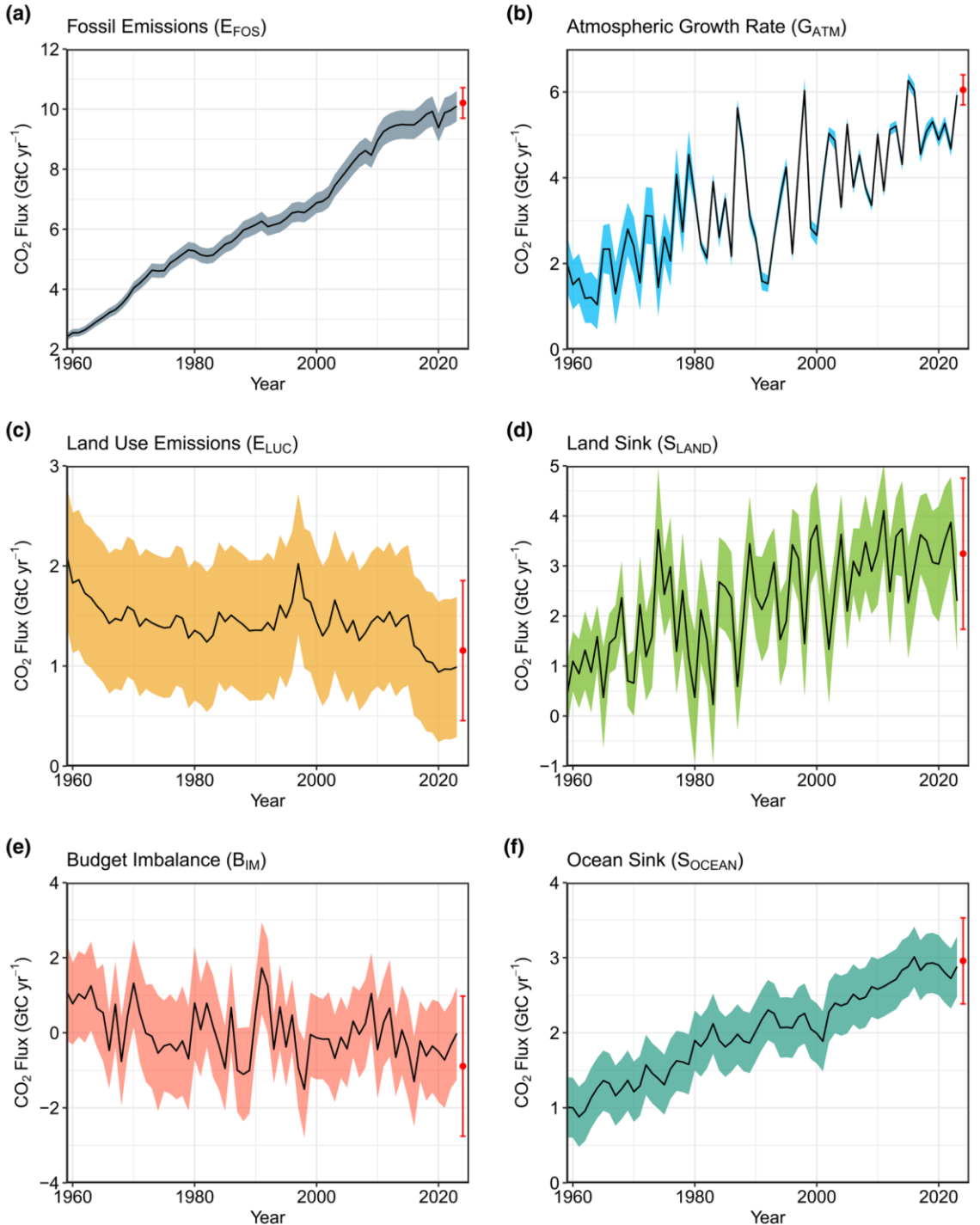
Anthropogenic fluxes
2014-2023 average
GtC per year

- Fossil CO_2 E_{FOS}
- Land-use change E_{LUC}
- CDR not included in E_{LUC}
- Land uptake S_{LAND}
- Ocean uptake S_{OCEAN}
- Atmospheric increase G_{ATM}
- Budget imbalance B_{IM}
- Stocks GtC
- Natural carbon fluxes in GtC

Friedlingstein et al. 2024

Global Carbon Budget

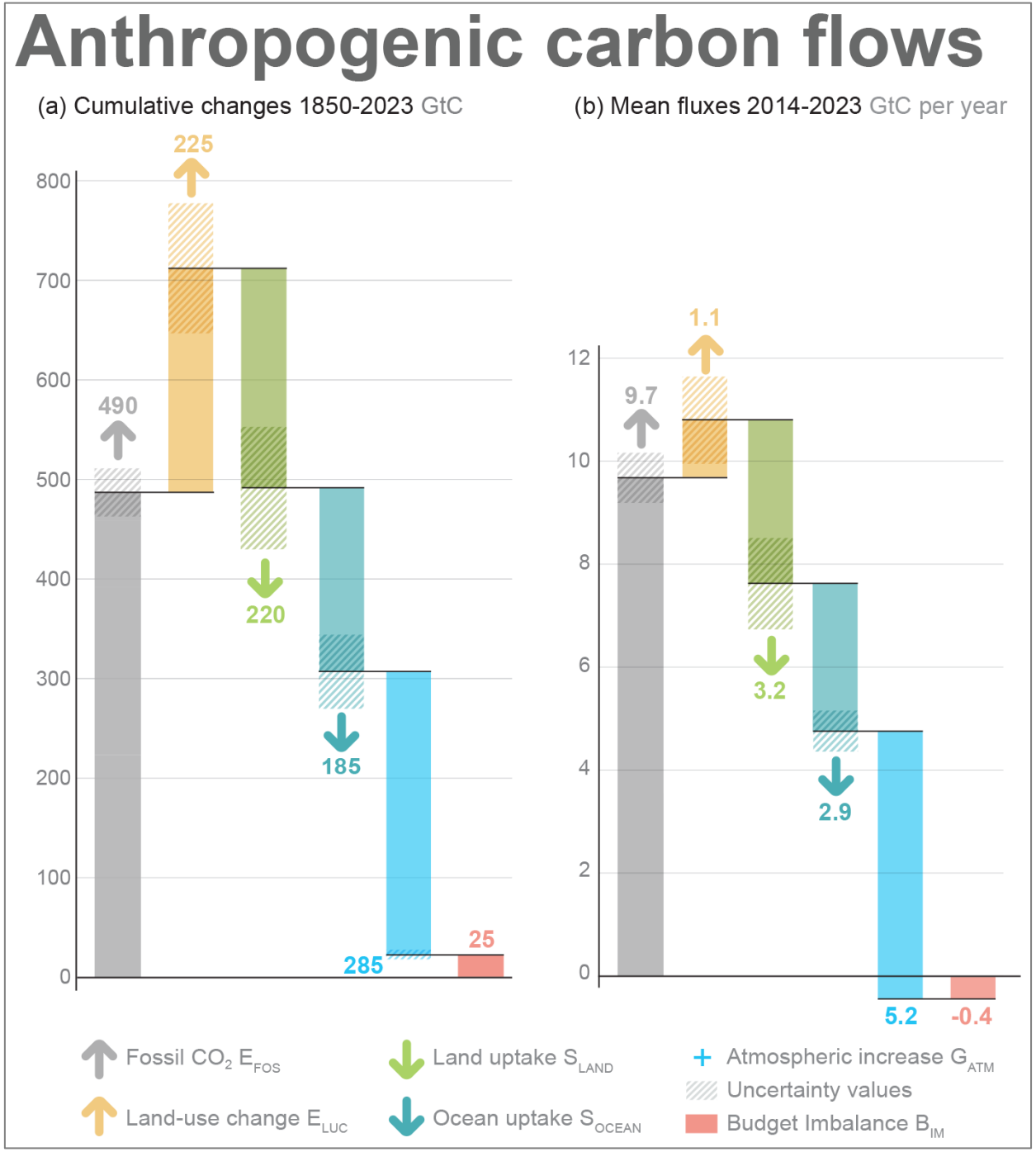
- Components of the global carbon budget and their uncertainties as a function of time
- Emissions from land use continue decline (stabilized)
- Sink strength from lands and oceans appear stabilized



Global Carbon Budget

Cumulative changes (1850–2023)

- 90 % of the total emissions (E_{FOS}+E_{LUC}) were from fossil CO_2 emissions (E_{FOS}) and 10 % from land-use change (E_{LUC}).
- The total emissions were partitioned among the atmosphere (48 %), ocean (26 %), and land (30 %),

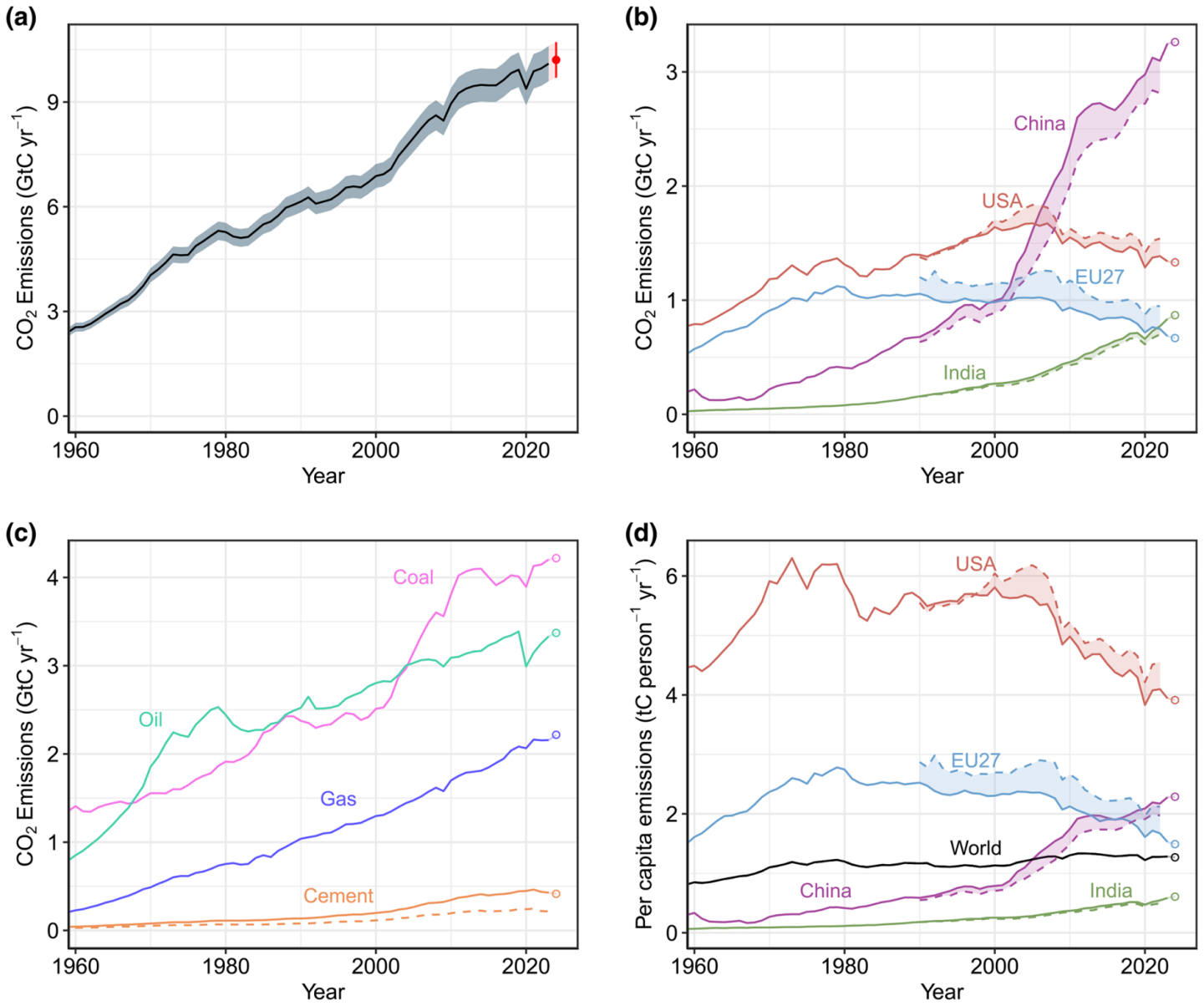


Global Carbon Budget

Fossil CO_2 emissions

- Different industries
- Major political entities
- Per capita

- Political debates (Paris Agreement)



Global Carbon Budget

Carbon Monitor: an open-access dataset (https://carbonmonitor.org/)

Carbon dioxide (CO_2) emissions from the use of fossil fuels and the production of cement are the main driving force of climate change. Carbon Monitor is an international initiative providing for the first time regularly updated, science-based estimates of daily CO_2 emissions. The data reveal the drop and re-growth of emissions during the COVID-19 pandemics.

Global Carbon Budget

1. Group Exercise: https://carbonmonitor.org/

   What did you find out?

2. How much CO_2 do you (or your family) add to the atmosphere from driving your car(s)?

Notes:

- Burning one gallon of regular gasoline emits ~19.6 lb of CO_2
- 1 ton of carbon = 3.667 ton of CO_2
- 1 ton of dry biomass is ~0.5 ton of carbon
- 87% of gasoline is carbon

Oct 27: Field Excision to Gustafson Farm

How are GHGs measured?