Computer Models

EES 2110

Introduction to Climate Change

Jonathan Gilligan

Class #26: Friday, March 10 2023

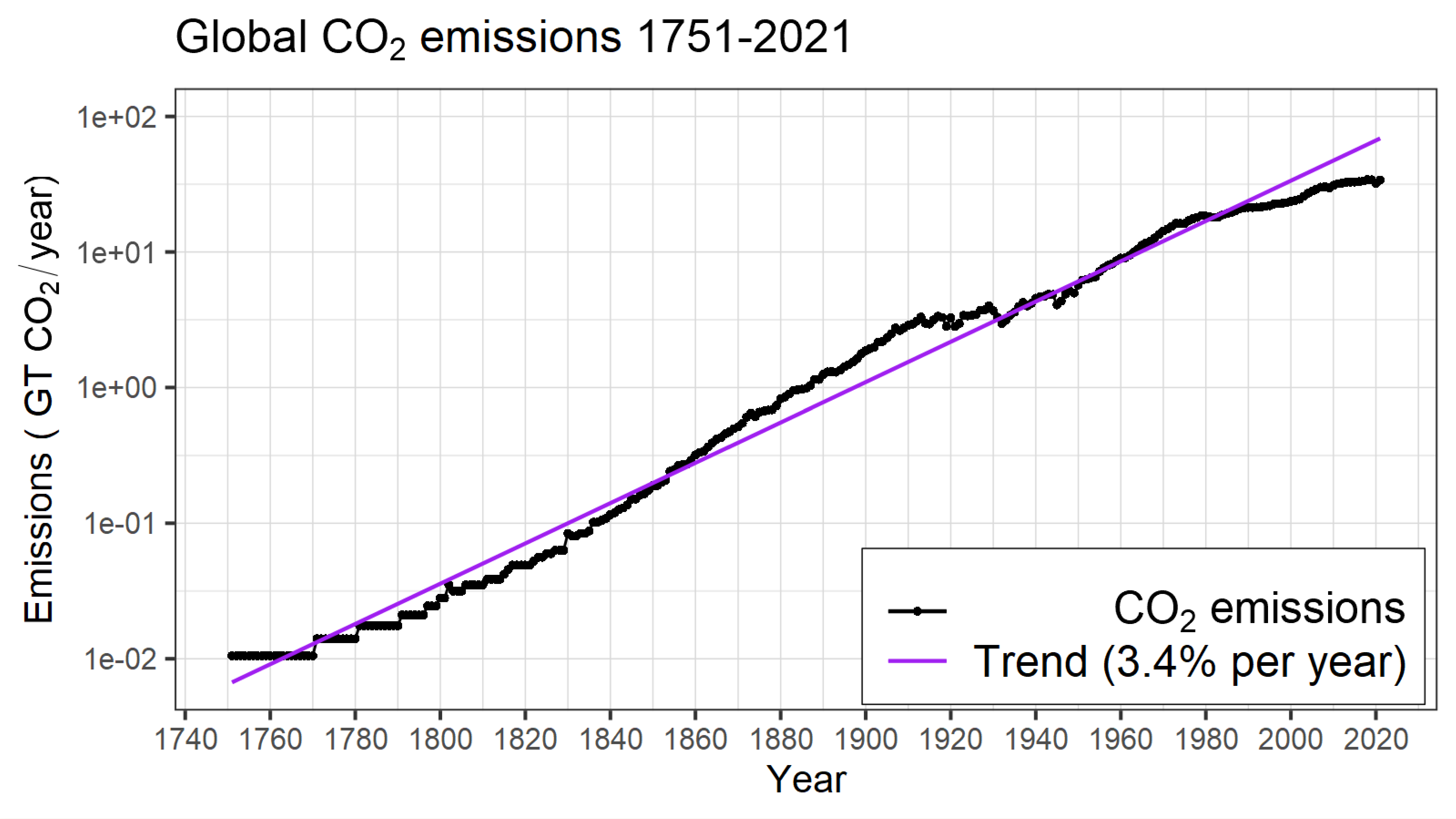
Climate and Economy

Climate and Economy

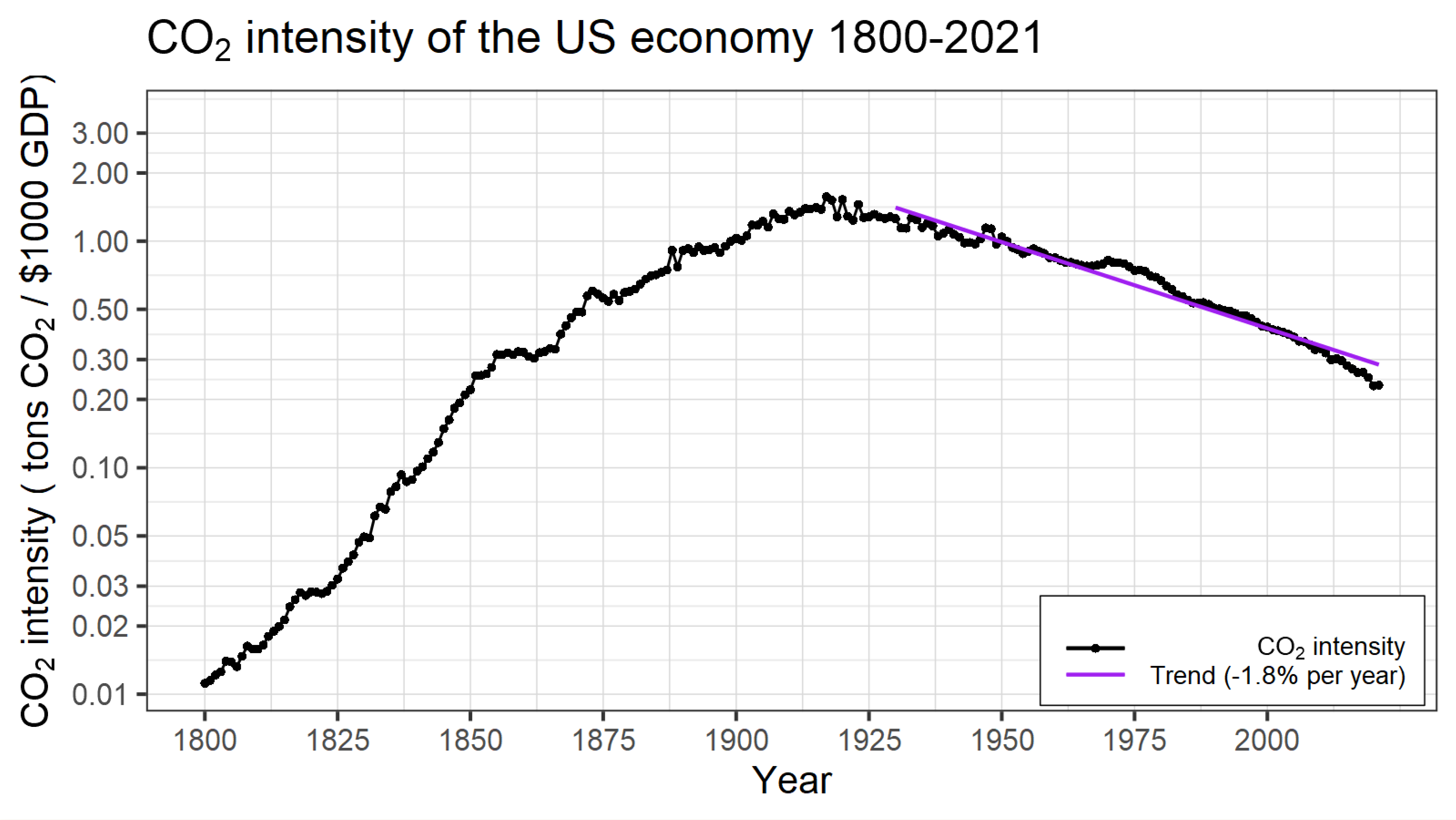
How well do markets manage global warming?

- How well do markets manage supply and price of bread?
- What is different about global warming?
- Externalities:
  - What is an externality?
  - Are externalities good or bad?
  - What challenges to they pose for markets?
  - How can market-based economies manage externalities better?

Energy, Economy, Emissions



Energy, Economy, Emissions



Kaya Identity

Kaya Identity

$$P \times \frac{G}{P} \times \frac{E}{G} \times \frac{F}{E} = F,$$

where

F = CO_2 emissions
E = energy use
G = gross domestic product
P = population

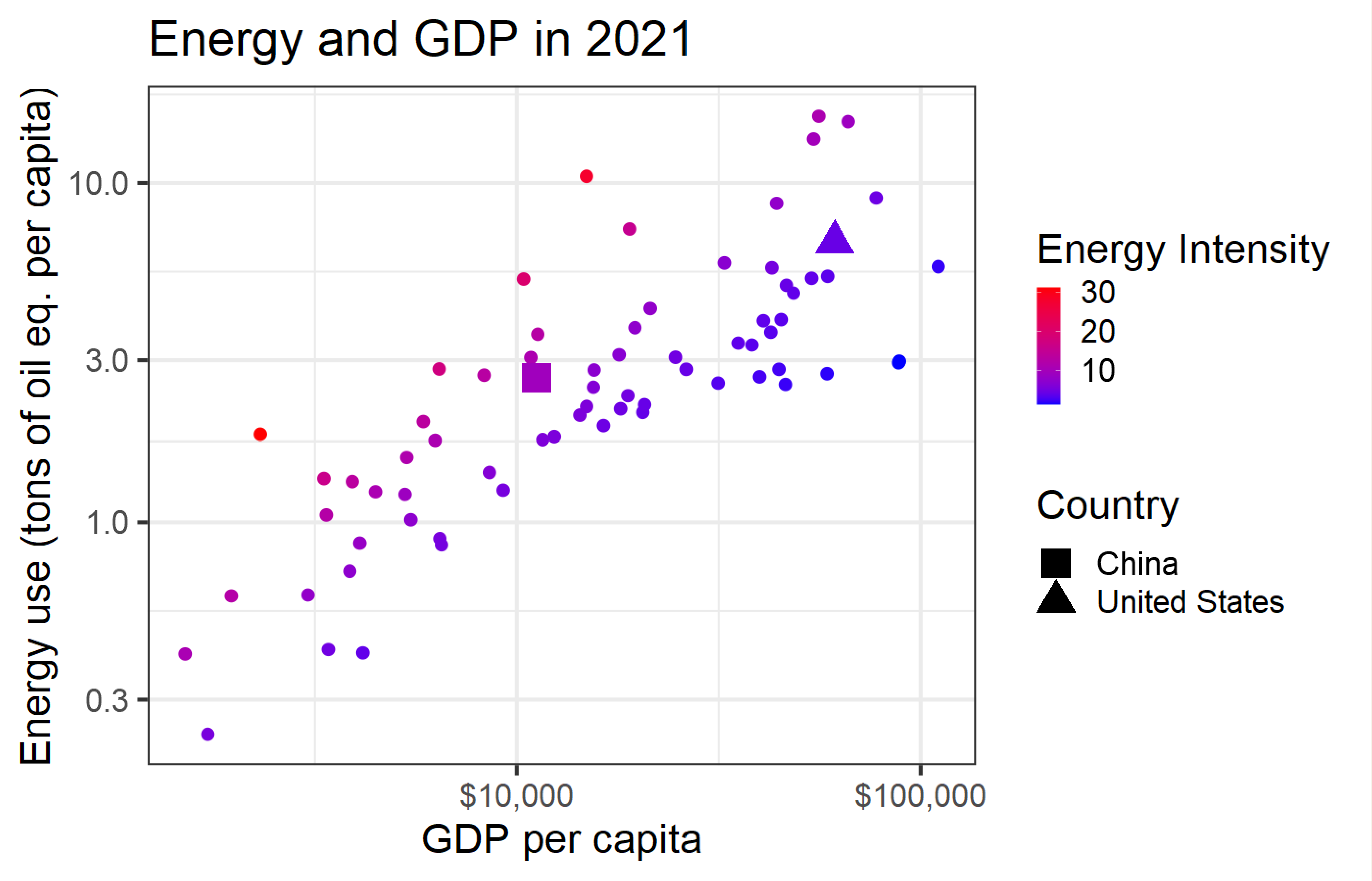
Kaya Identity

$$F = P \times \frac{G}{P} \times \frac{E}{G} \times \frac{F}{E}$$
$$= P \times g \times e \times f$$

where

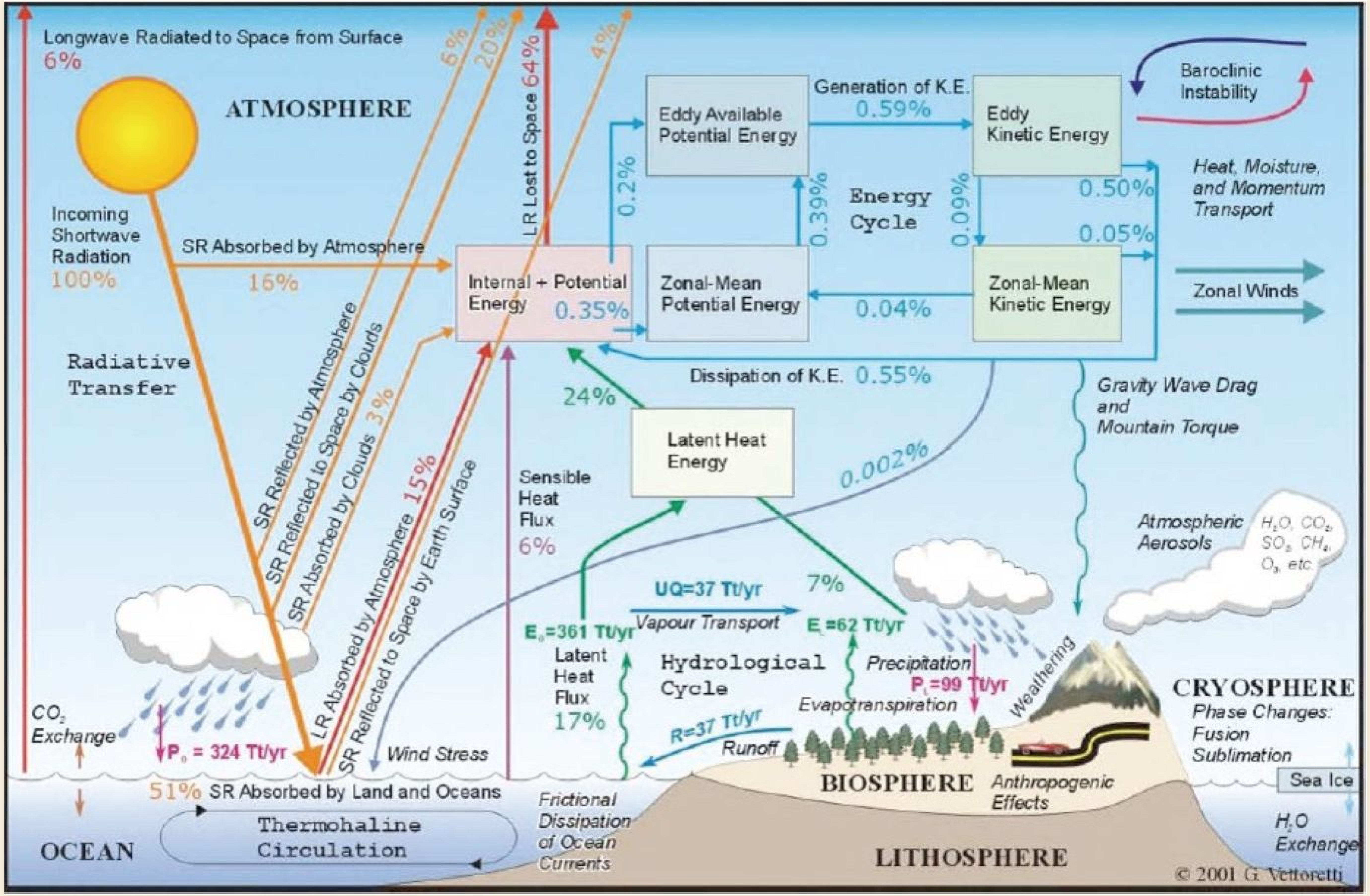
$$P = \text{population}$$
$$g = G/P = \text{per-capita GDP}$$
$$e = E/G = \text{energy intensity of economy}$$
$$f = F/E = \text{CO}_2 \text{ intensity of energy supply}$$

Kaya Identity in Practice

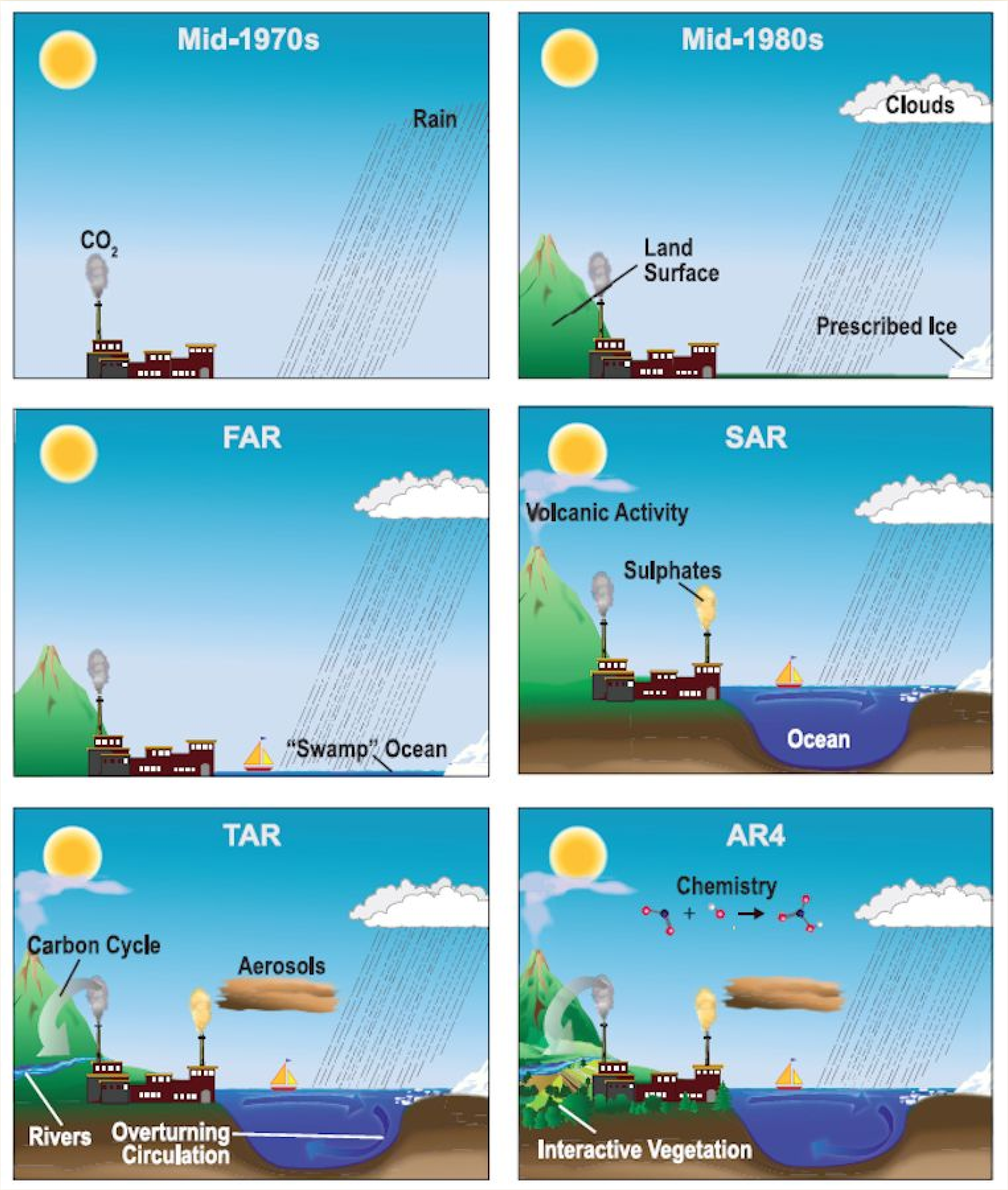


Computer Models of Climate

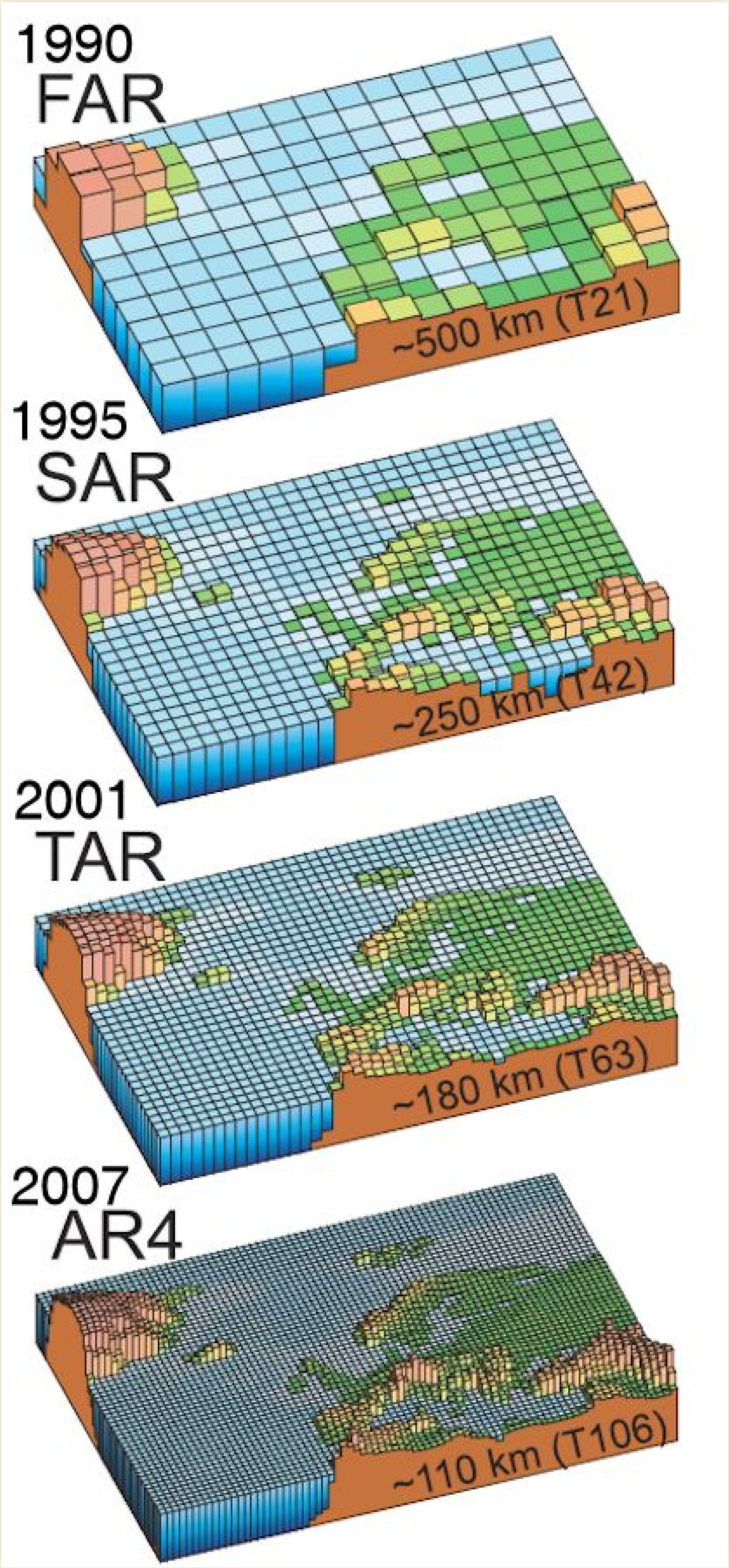
Computer Models of Climate

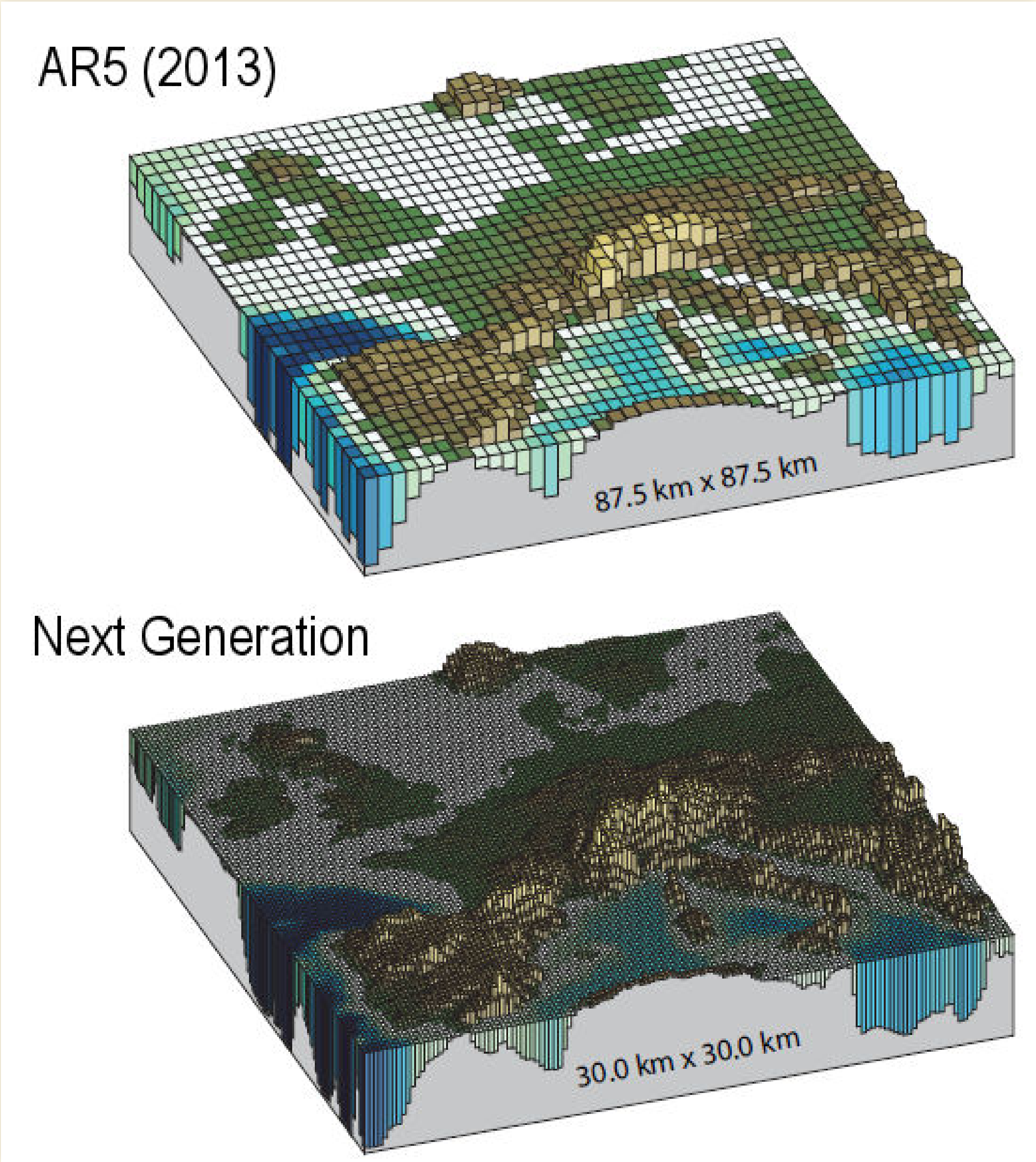


Computer Models



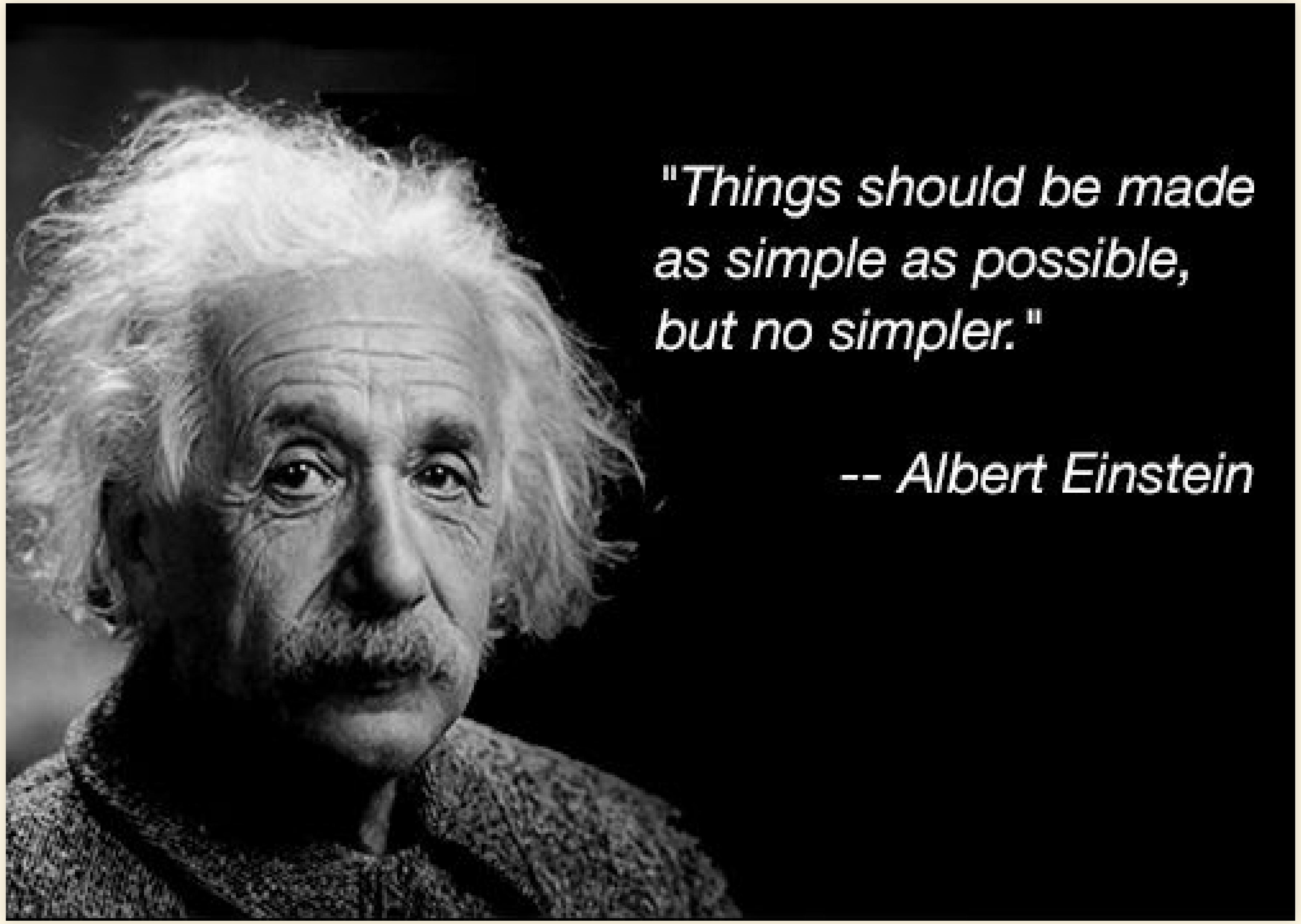
Computer Models





Principles of Computer Modeling

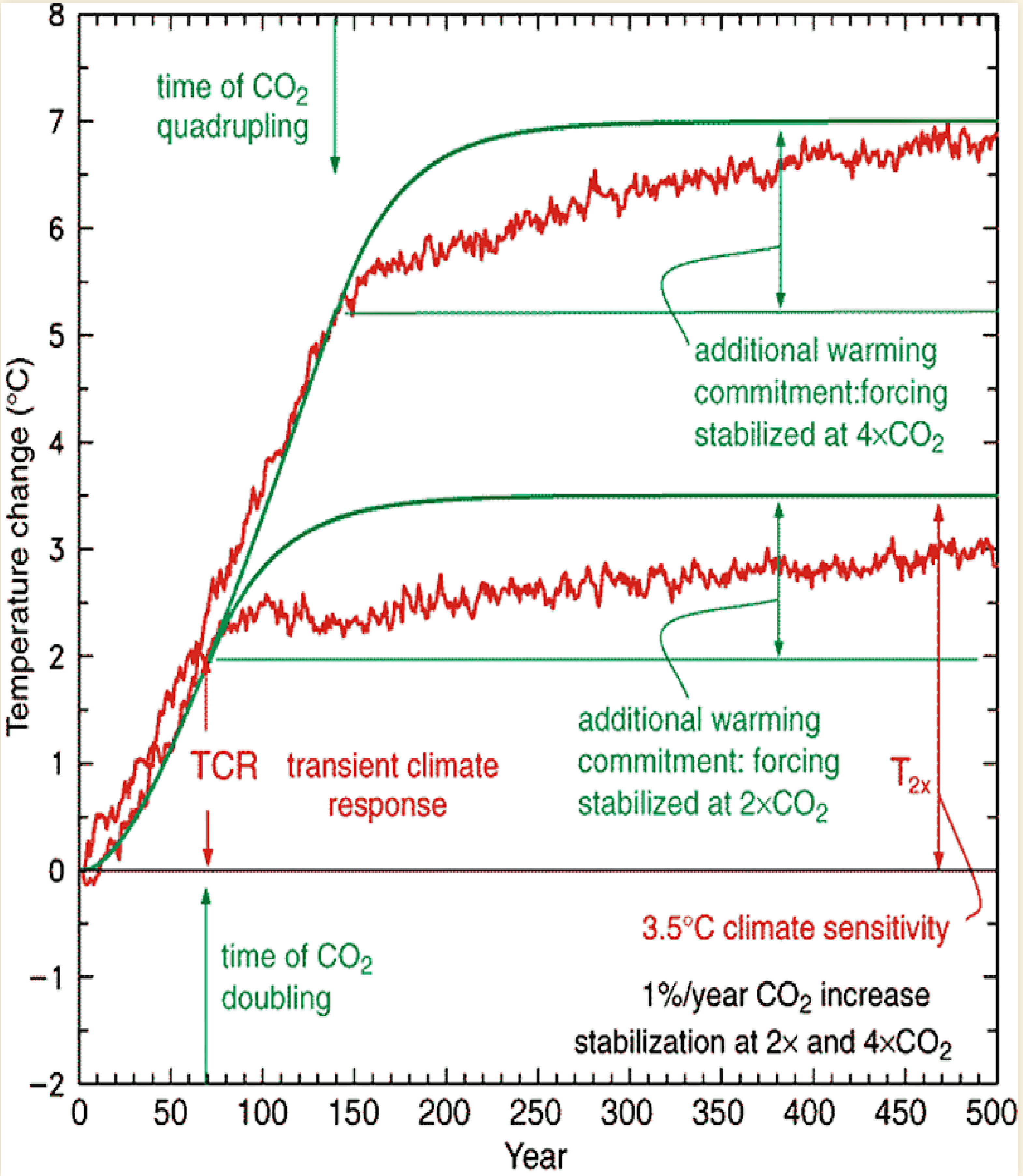
- Make models as simple as possible:
  - Start simple
  - Add complexity only as needed
    - Different models for different purposes
  - Check model against real world



Transient vs.
Equilibrium Response

Transient vs. Equilibrium Response

- Gradually raise CO_2 and then stop.
- Planet takes time to heat up
  - Oceans absorb heat
  - Like pot of water on stove
- Transient response:
  ΔT when CO_2 stops changing
- Equilibrium response:
  Stable temperature (much later)
  - Green: Atmosphere & surface ocean
  - Red: Atmosphere, surface ocean, & deep ocean.
- Equilibrium takes many decades.



Modeling for Science vs. Policy

Modeling for Science vs. Policy

Integrated Assessment Models (IAMS)

- Combine climate system and world economy
  - Emissions as a consequence of economic activity
    - Energy use for production (factories, etc.)
    - Energy use for consumption (households, etc.)
    - Farming: fertilizers, livestock, paddy fields, etc.
  - Climatic impacts on economy
    - Cost of severe weather
    - Sea level rise
    - Droughts & heat waves
    - ...
- **Optimize for greatest net economic output**

Climate Projections

- Biggest uncertainty in predicting future climates is GHG emissions
  - We can predict consequences of emissions
  - We can’t predict what emissions will be
- Scenarios and Pathways:
  - **Scenario**: possible future,
    - Story of economic & political development $\rightarrow$ resulting emissions
  - **Pathway**: possible future,
    - Trajectory of emissions $\rightarrow$ economic activity that might cause them
- Projections:
  - Conditional predictions:
    - “**If** emissions do this, **then** climate will do that.”

Projections for future emissions in US:

	2010	**2050**	**Growth rate**
g ($/person)	42,300	83,495	1.7%
ef (tons/$million)	432	228	-1.6%
P (millions)	309	393	0.6%
Total Emissions *F* (million tons CO_2)	**5,647**	**7,471**	1.7 - 1.6 + 0.6 = **0.7%**

Projections for future world emissions:

	2010	**2050**	**Growth rate**
g ($/person)	9,780	22,654	2.1%
ef (tons/$million)	522	275	-1.6%
P (millions)	6,410	9,188	0.9%
Total Emissions *F* (million tons CO_2)	**32,724**	**57,289**	2.1 - 1.6 + 0.9 = **1.4%**

Uncertainties in Projections

Projections for future world emissions:

	2010	**2050**	**2100**	**Growth rate**
g ($/person)	9,780	22,654	64,737	2.1%
ef (tons/$million)	522	275	124	-1.6%
P (millions)	6,410	9,188	14,409	0.9%
Total Emissions *F* (million tons CO_2)	**32,724**	**57,289**	**115,366**	**1.4%**

Uncertainties in Projections

Projections for future world emissions with slightly different growth rates:

	2010	2050	2100	Growth rate	Δ rate
g ($/person)	9,780	24,541	77,505	2.3%	0.2%
ef (tons/$million)	522	298	148	-1.4%	0.2%
P (millions)	6,410	9,563	15,766	1.0%	0.1%
Total Emissions F (million tons CO_2)	**32,724**	**69,973**	**180,930**	**1.9%**	0.5%
Difference		**12,684**	**65,564**	**0.5%**	
Difference (%)		**22%**	**57%**		