Computer Models

EES 3310/5310

Global Climate Change

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Class #16: 2022-02-23 2022

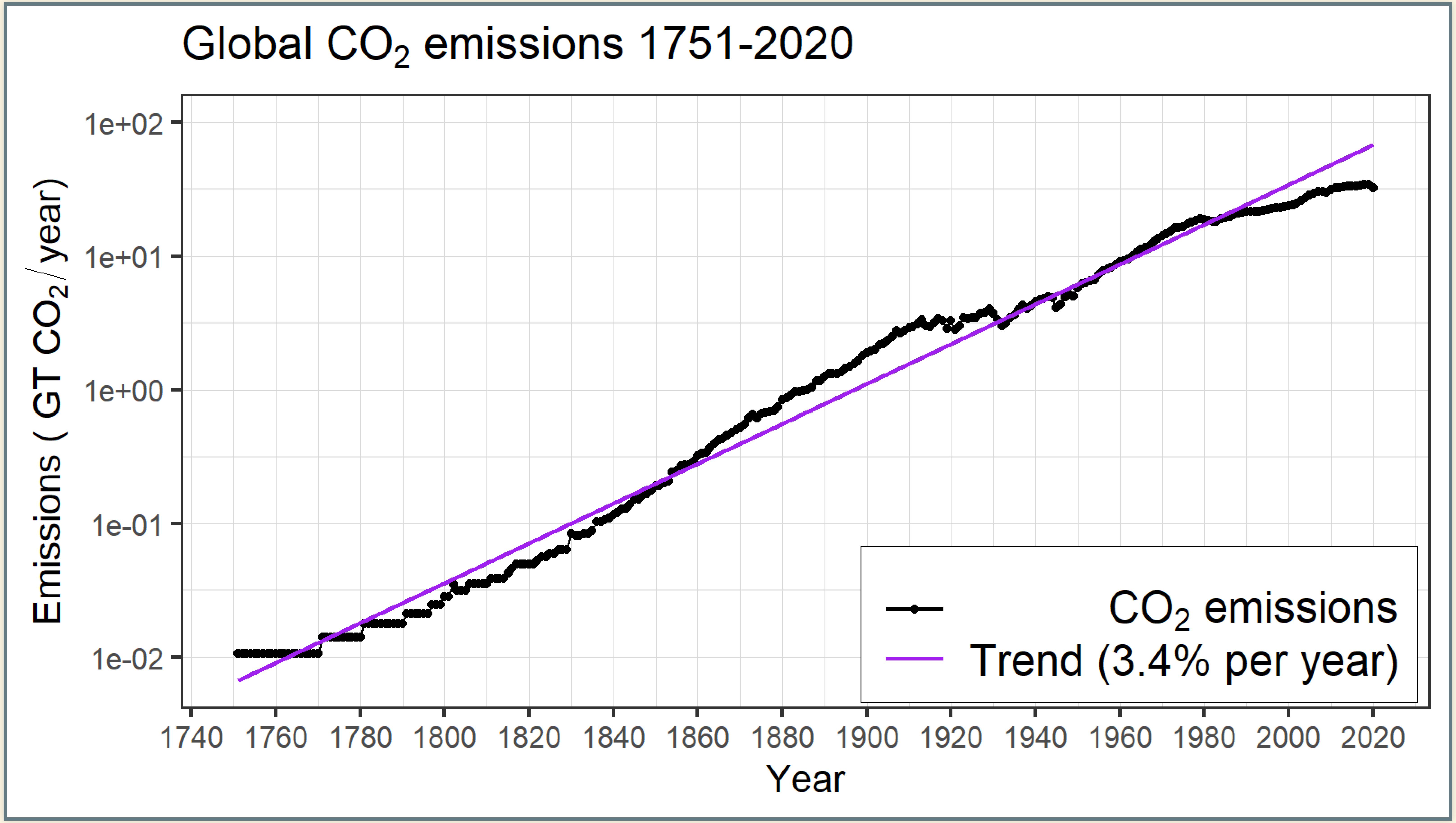
Climate and Economy

Climate and Economy

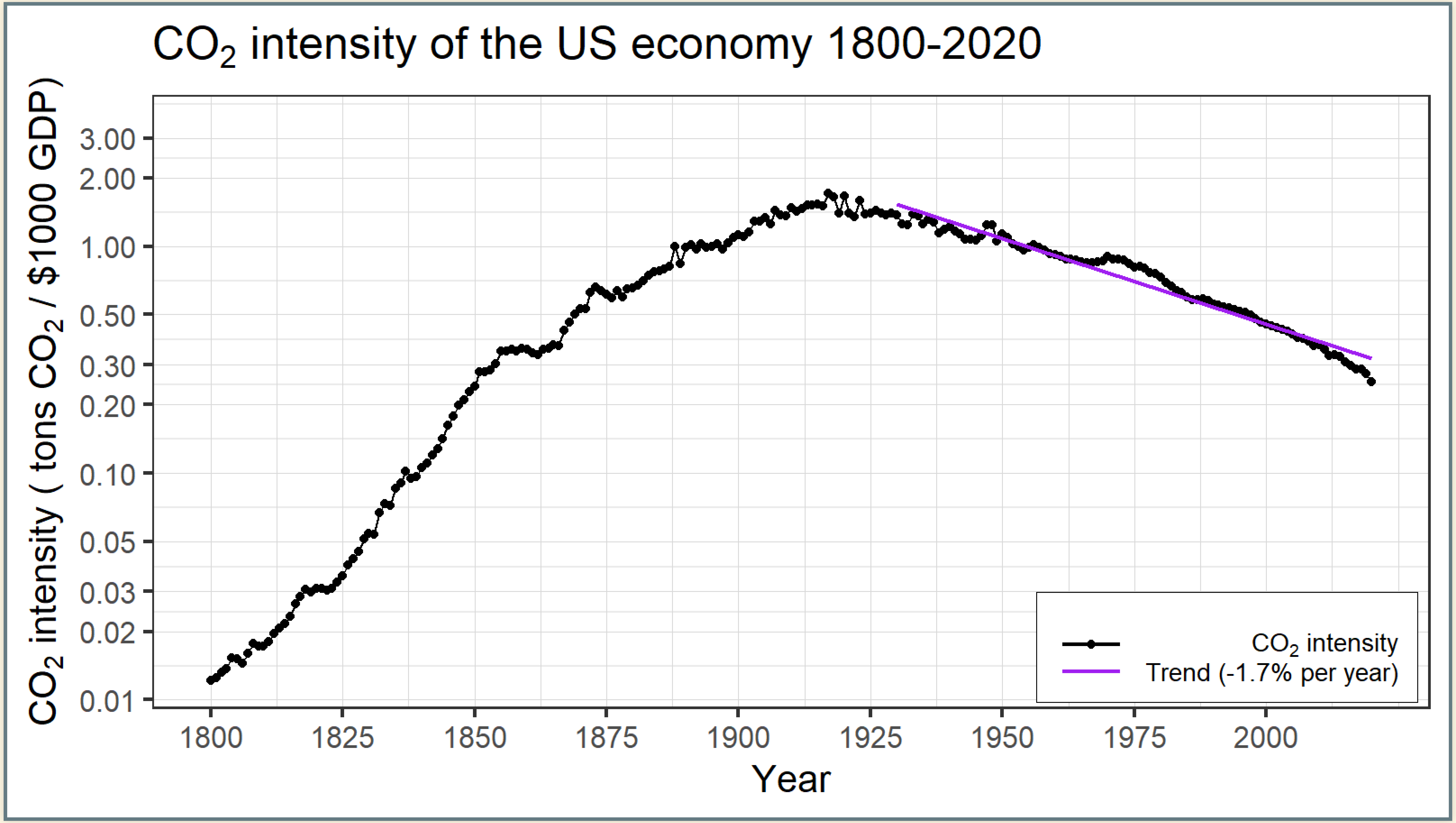
How well do markets manage global warming?

- 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

\[\color{darkgreen}{P} \times \frac{\color{blue}{G}}{\color{darkgreen}{P}} \times \frac{\color{purple}{E}}{\color{blue}{G}} \times \frac{\color{red}{F}}{\color{purple}{E}} = \color{red}{F}, \]

where

\[\begin{aligned} \color{red}{F} &= \COO~\text{emissions}\\ \color{purple}{E} &= \text{energy use}\\ \color{blue}{G} &= \text{gross domestic product}\\ \color{darkgreen}{P} &= \text{population} \end{aligned} \]

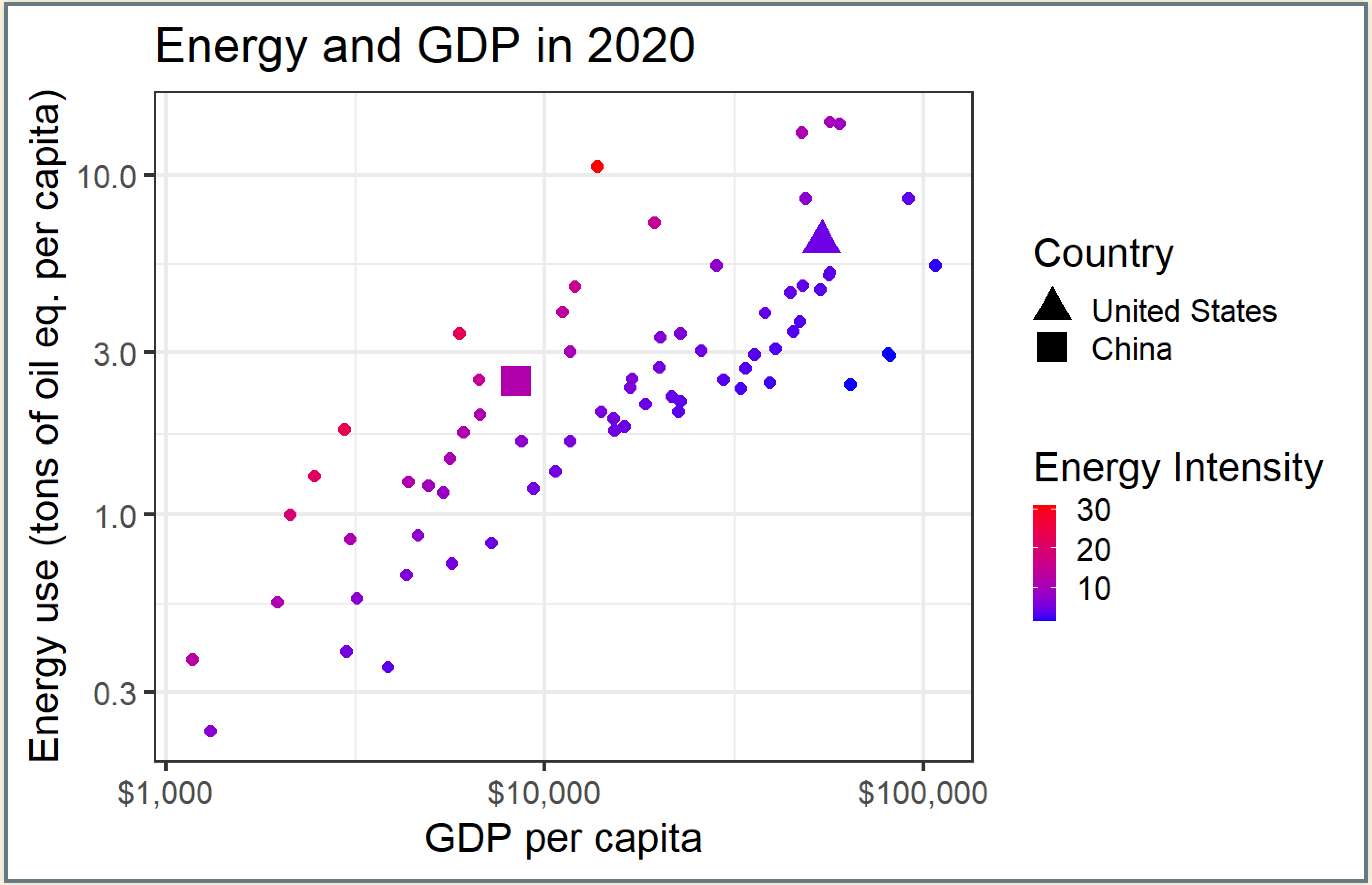
Kaya Identity

\[\begin{aligned} \color{red}{F} &= \color{darkgreen}{P} \times \frac{\color{blue}{G}}{\color{darkgreen}{P}} \times \frac{\color{purple}{E}}{\color{blue}{G}} \times \frac{\color{red}{F}}{\color{purple}{E}}\\ &= \color{darkgreen}{P} \times \color{blue}{g}\times \color{purple}{e} \times \color{red}{f}\\ \end{aligned}\]

where

\[\begin{aligned} \color{darkgreen}{P} &= \text{population}\\ \color{blue}{g} &= \color{blue}{G} / \color{darkgreen}{P} = \text{per-capita GDP}\\ \color{purple}{e} &= \color{purple}{E} / \color{blue}{G} = \text{energy intensity of economy}\\ \color{red}{f} &= \color{red}{F} / \color{purple}{E} = \COO~\text{intensity of energy supply} \end{aligned}\]

Kaya Identity in Practice



Computer Models of Climate

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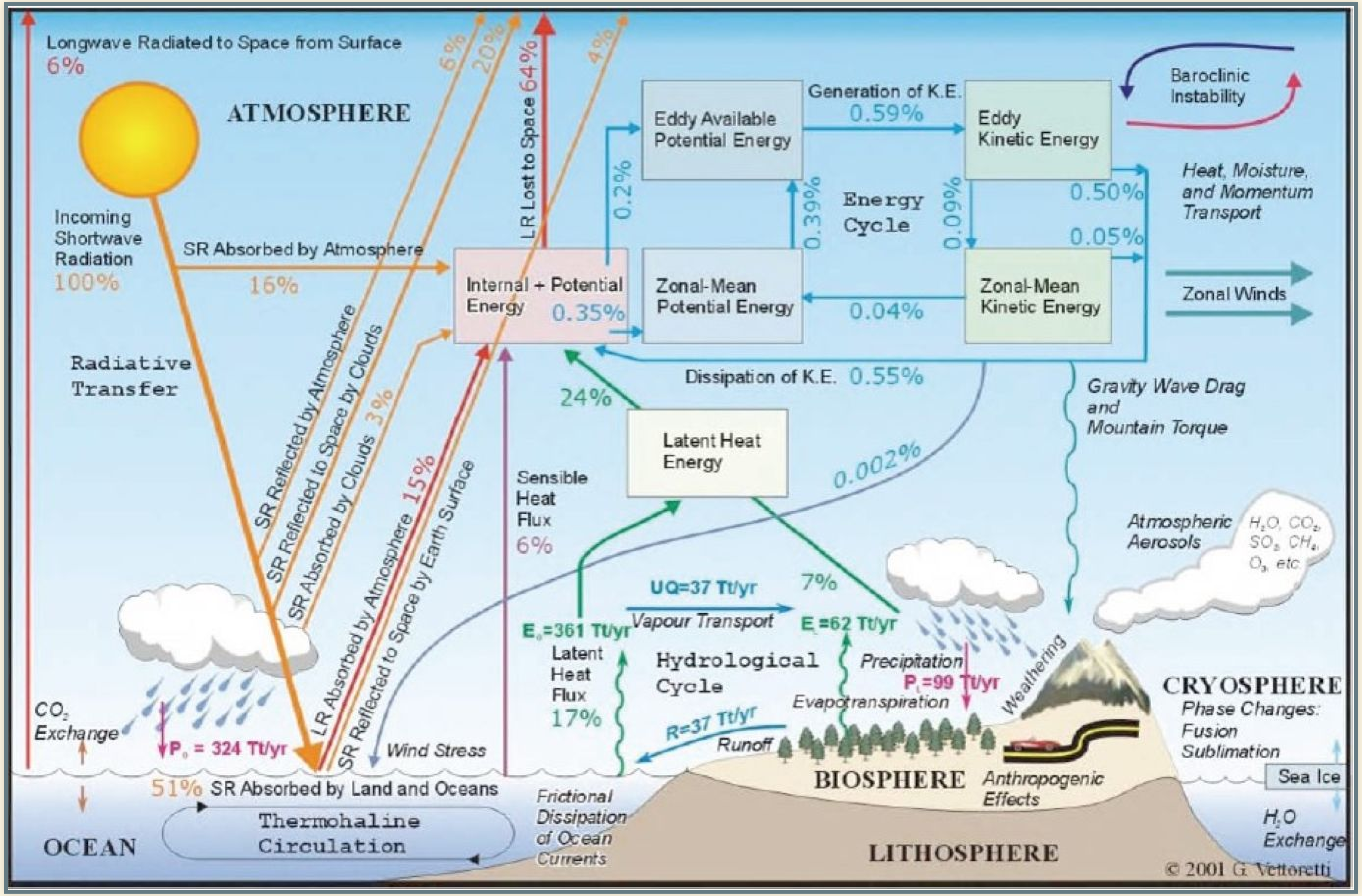
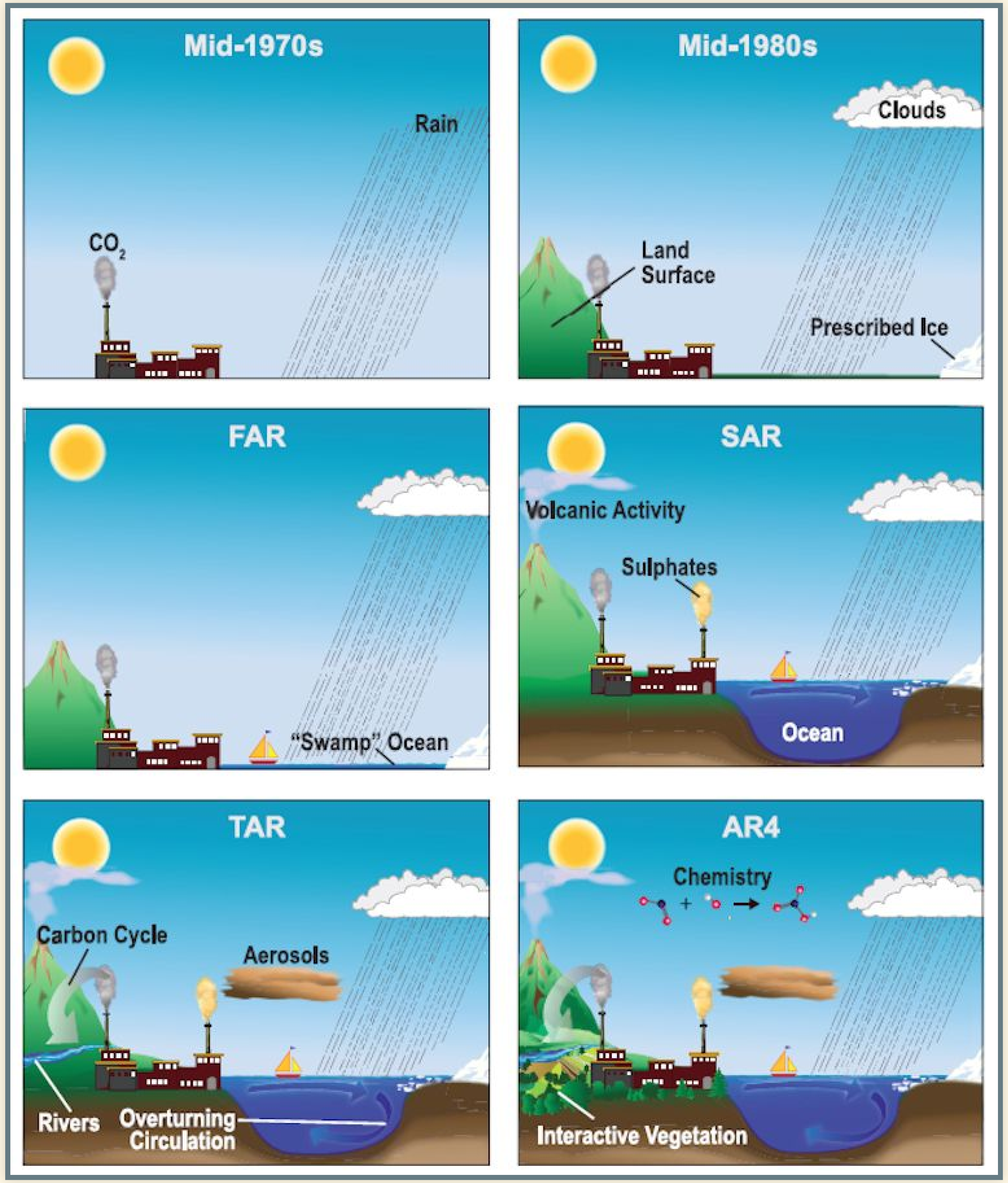
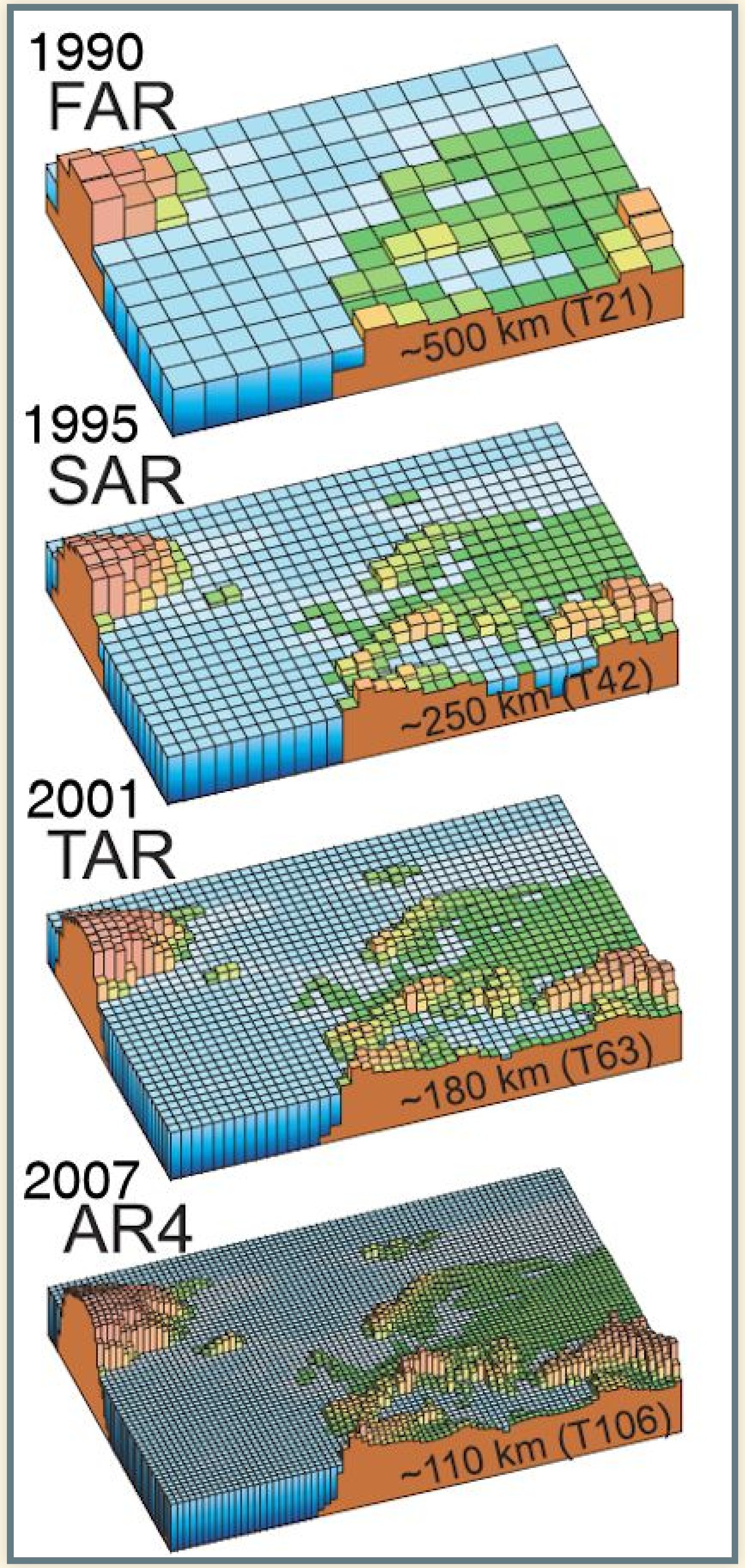
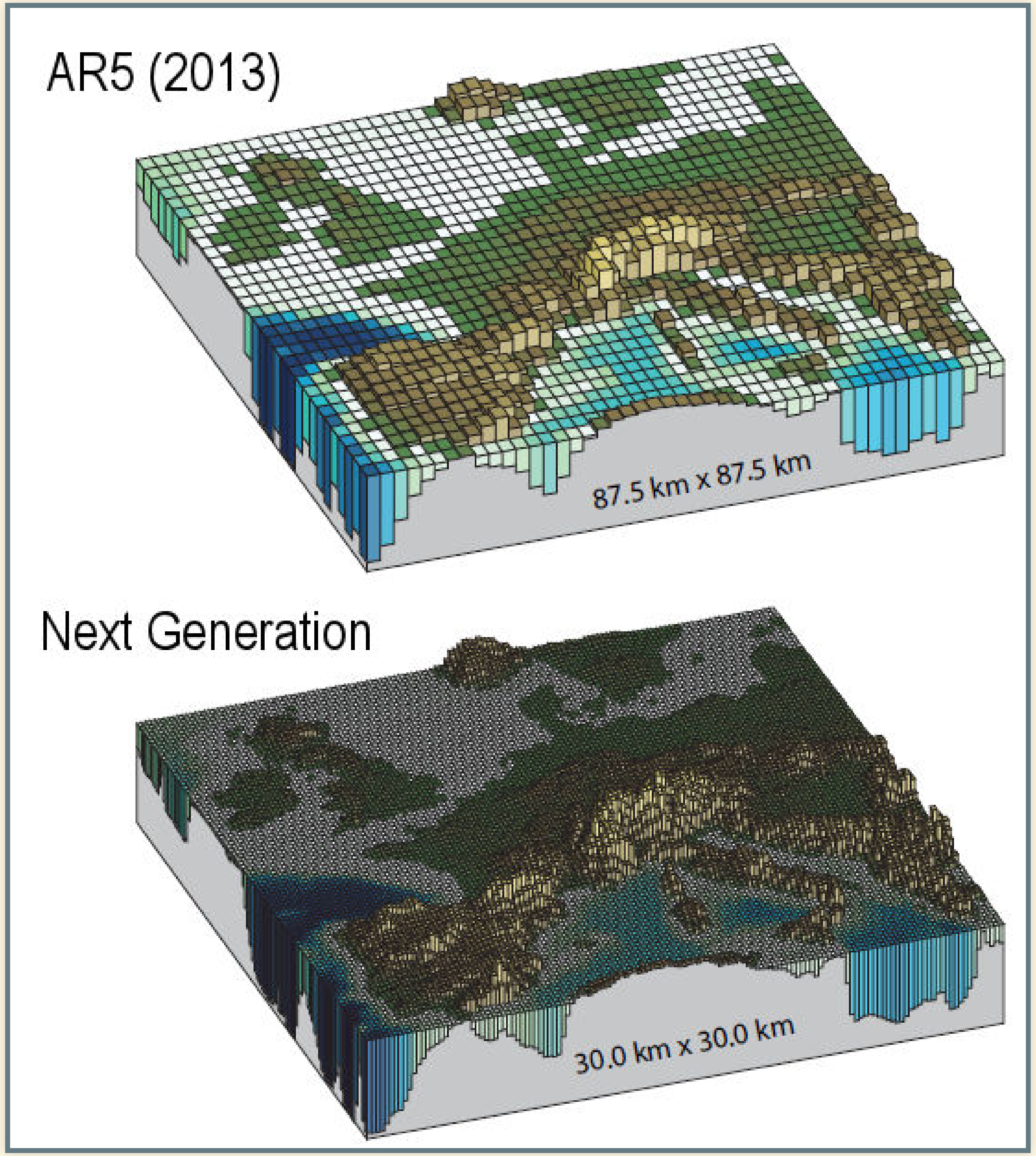


Computer Models



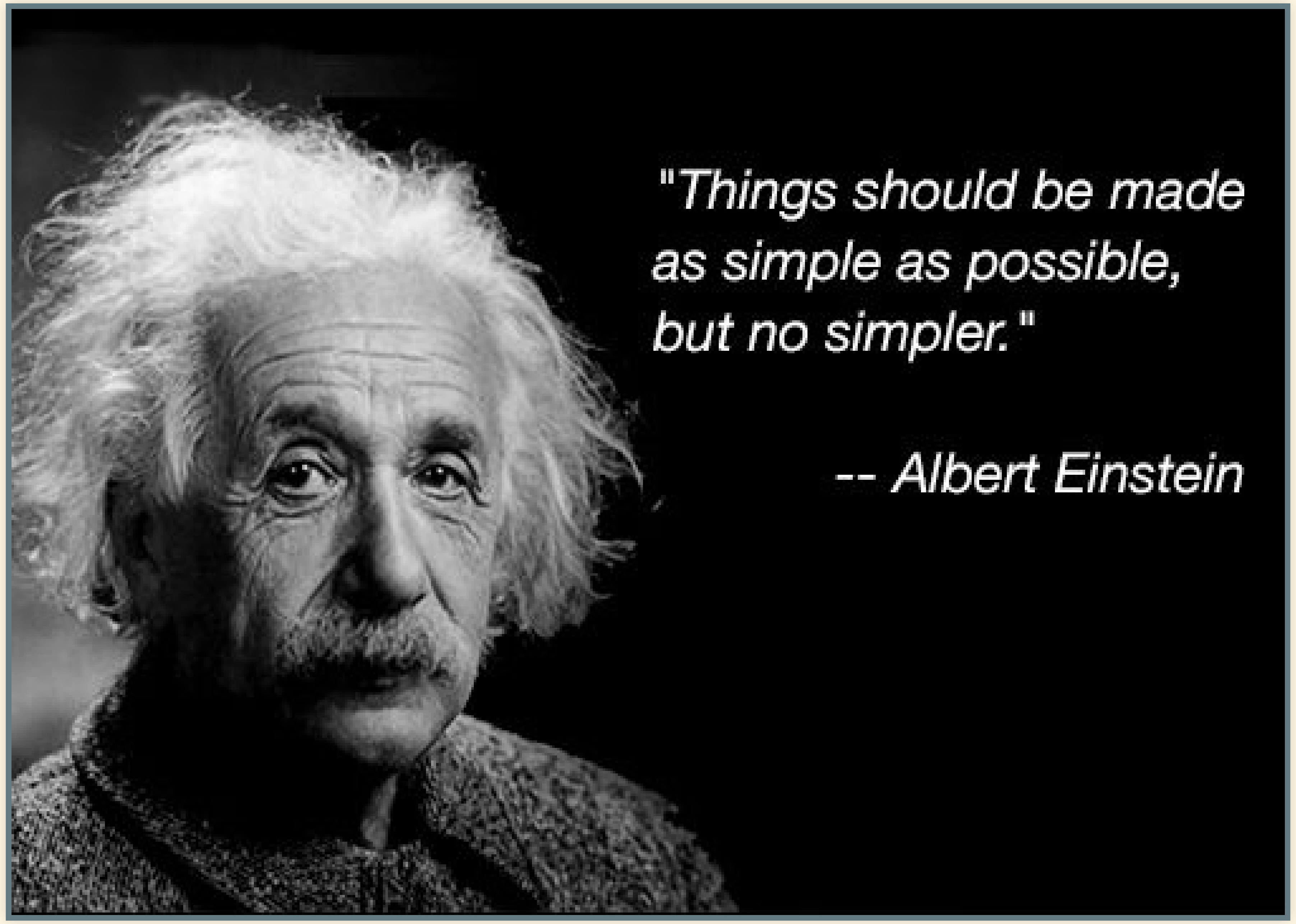
Computer Models





Principles of Computer Modeling

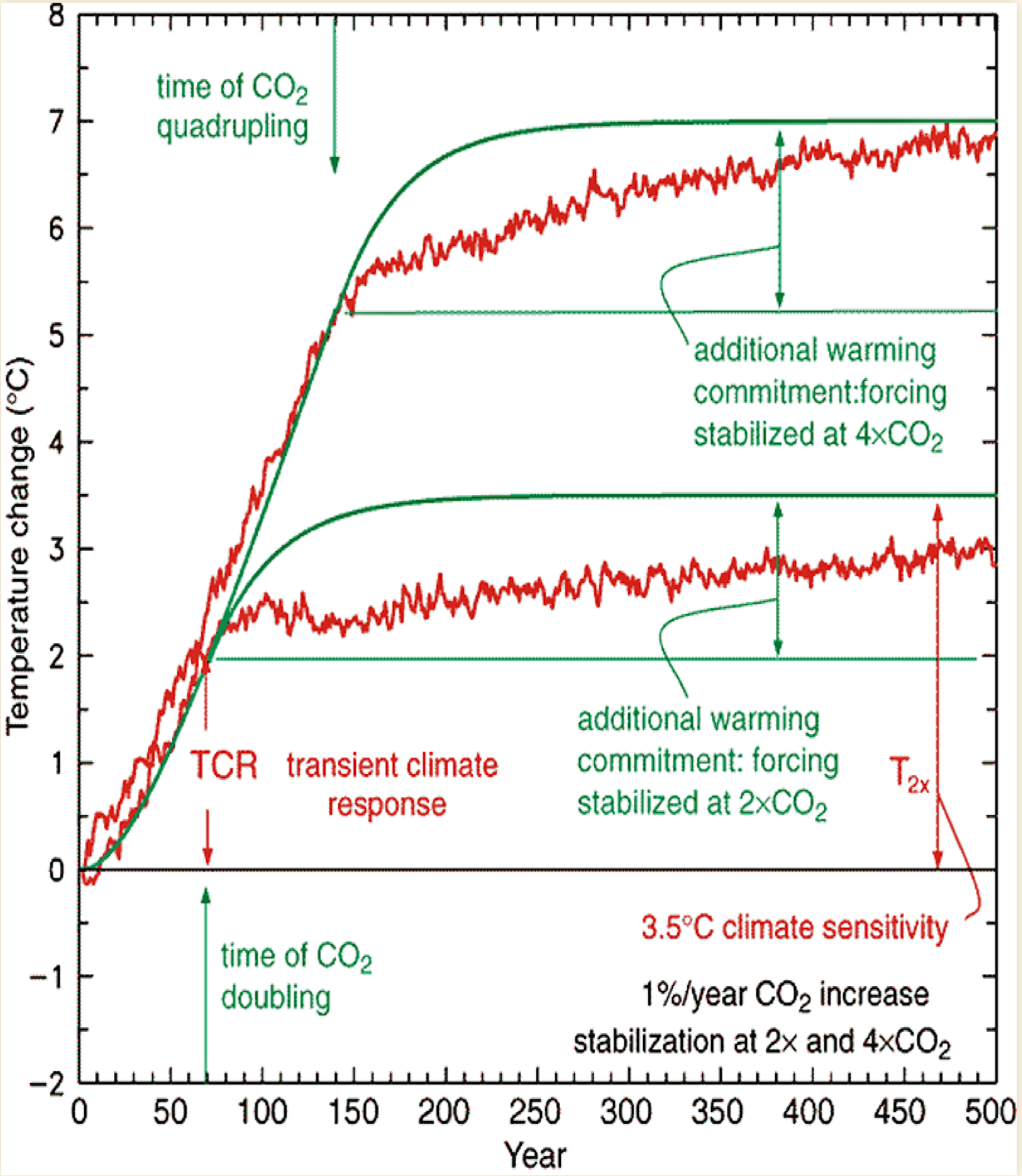
- Make models as simple as possible:
    - Start simple
    - Add complexity only as needed
        - Different models for different purposes
    - Check model against real world



Transient vs.
Equilibrium Response

Transient vs. Equilibrium Response

- Gradually raise \(\COO\) and then stop.
- Planet takes time to heat up
  - Oceans absorb heat
  - Like pot of water on stove
- Transient response:
  \(\Delta T\) when \(\COO\) 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%**		