# Computer Models

EES 3310/5310

Global Climate Change

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Class #16: Wednesday, Sept. 27 2018

# Midterm Exam

- In class next Wednesday (Oct. 3)
- Bring #2 pencils, eraser, and calculator
- Test will provide important numbers and equations:
- You need to know how to tell:
  - which equations, numbers to use,
  - how to interpret them.
- Mostly conceptual questions, not so many with math
- Practice test with answers on Brightspace

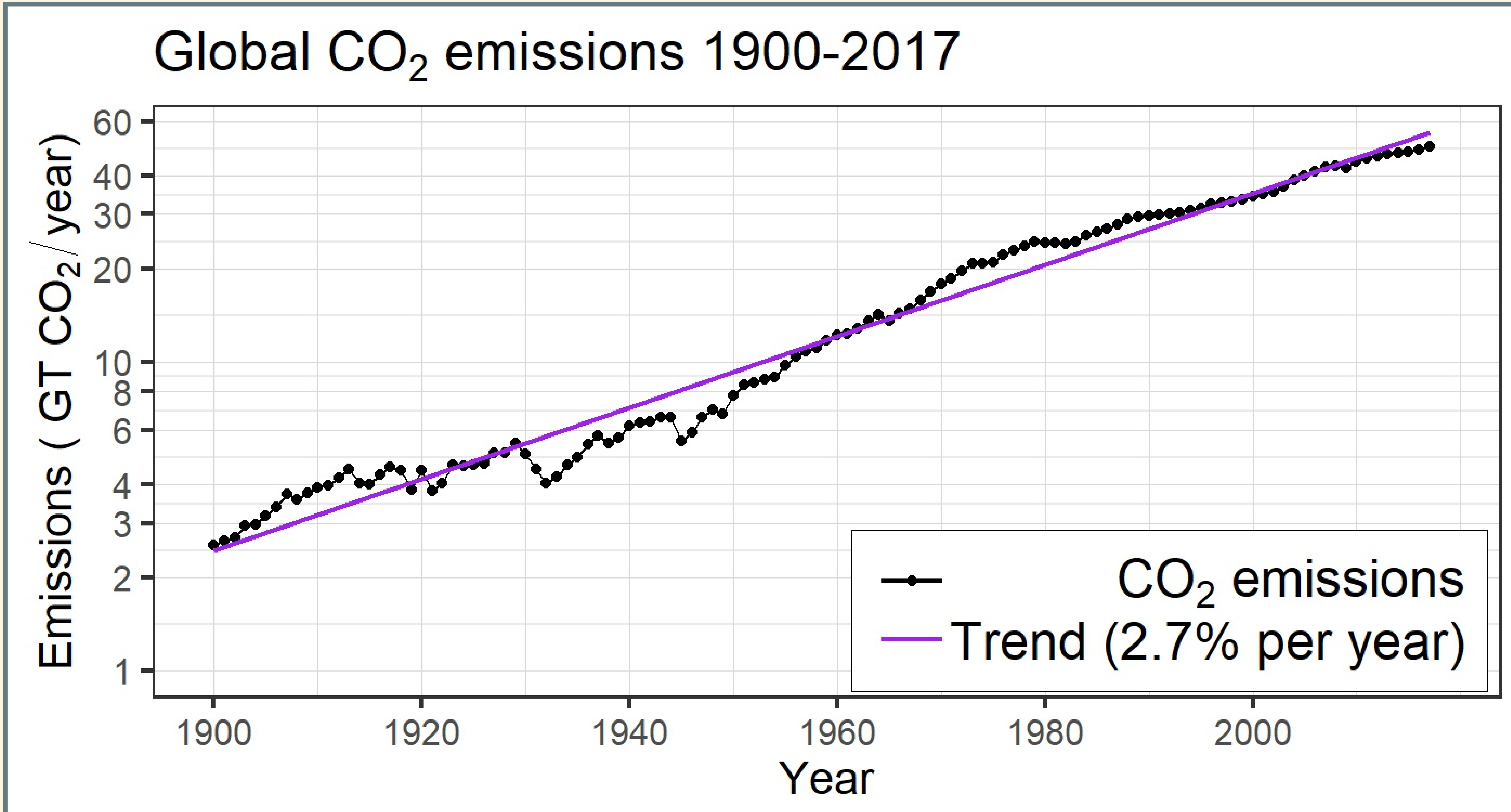
# Climate and Economy

# Climate and Economy

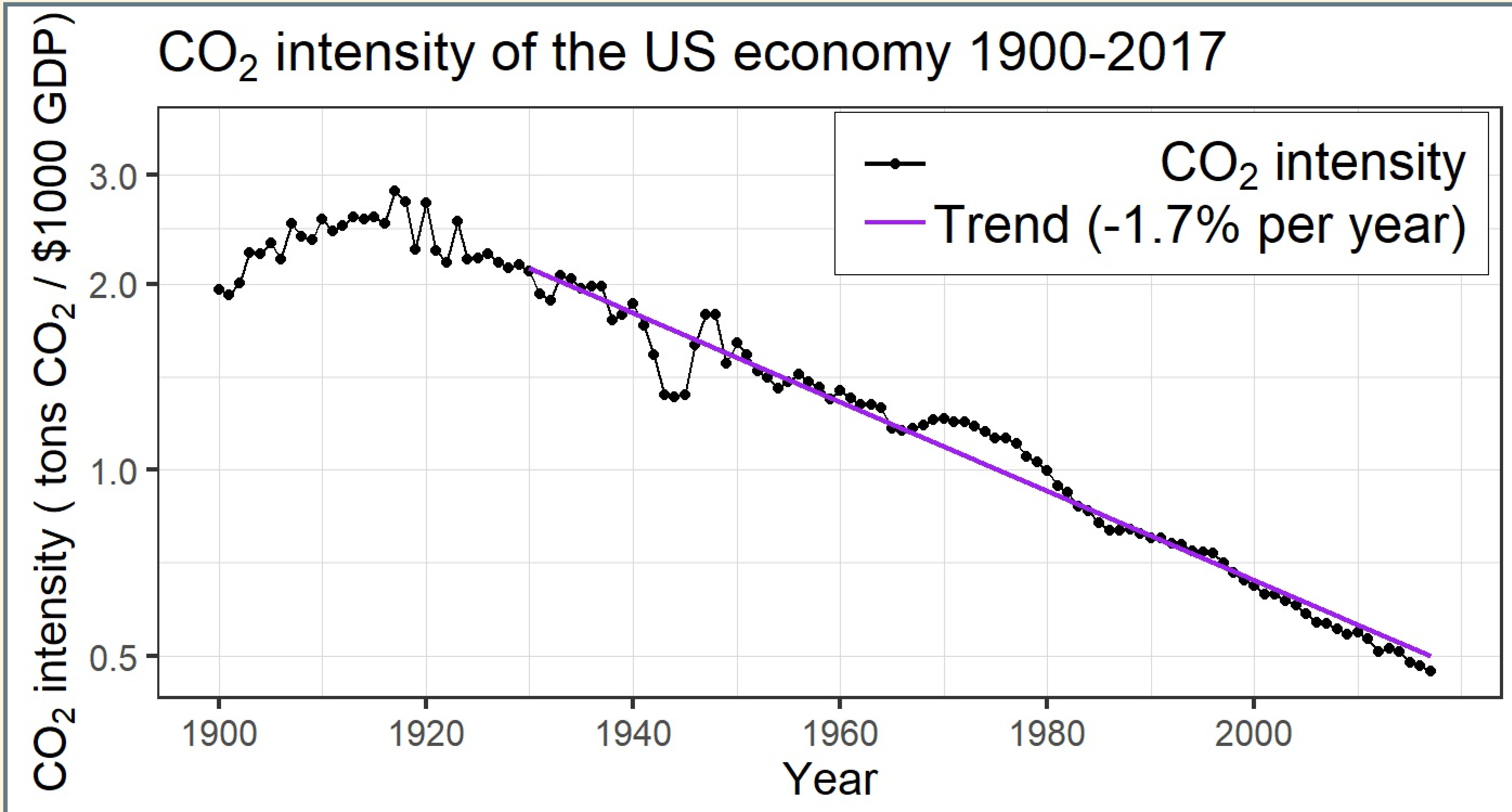
## **How well do markets manage global warming?**

- 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

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

**where**

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

# Kaya Identity

$$\begin{aligned} F &= P \times \frac{G}{P} \times \frac{E}{G} \times \frac{F}{E} \\ &= P \times g \times e \times f \end{aligned}$$

## where

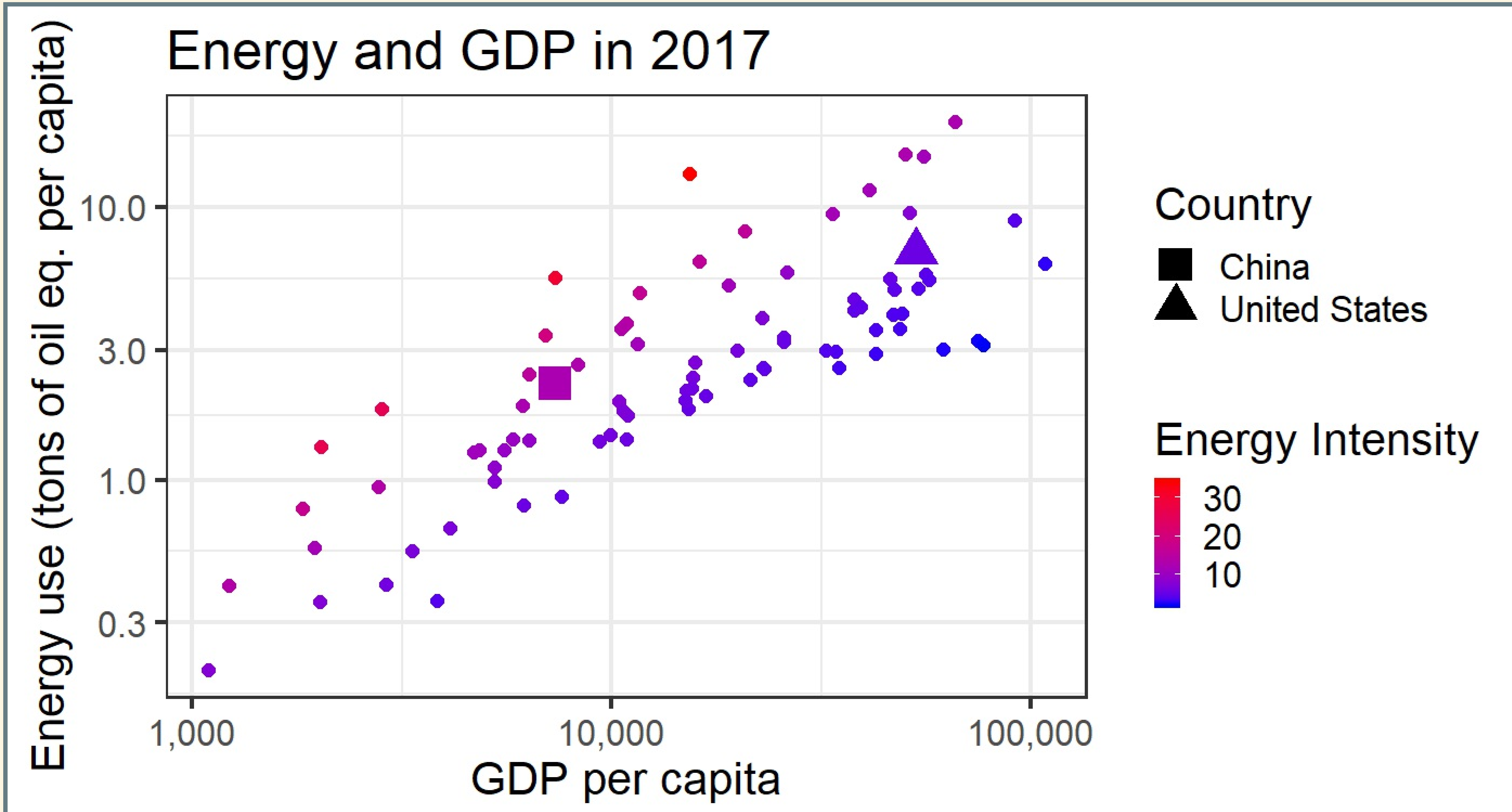
$P =$ population

$g = G/P =$ per-capita GDP

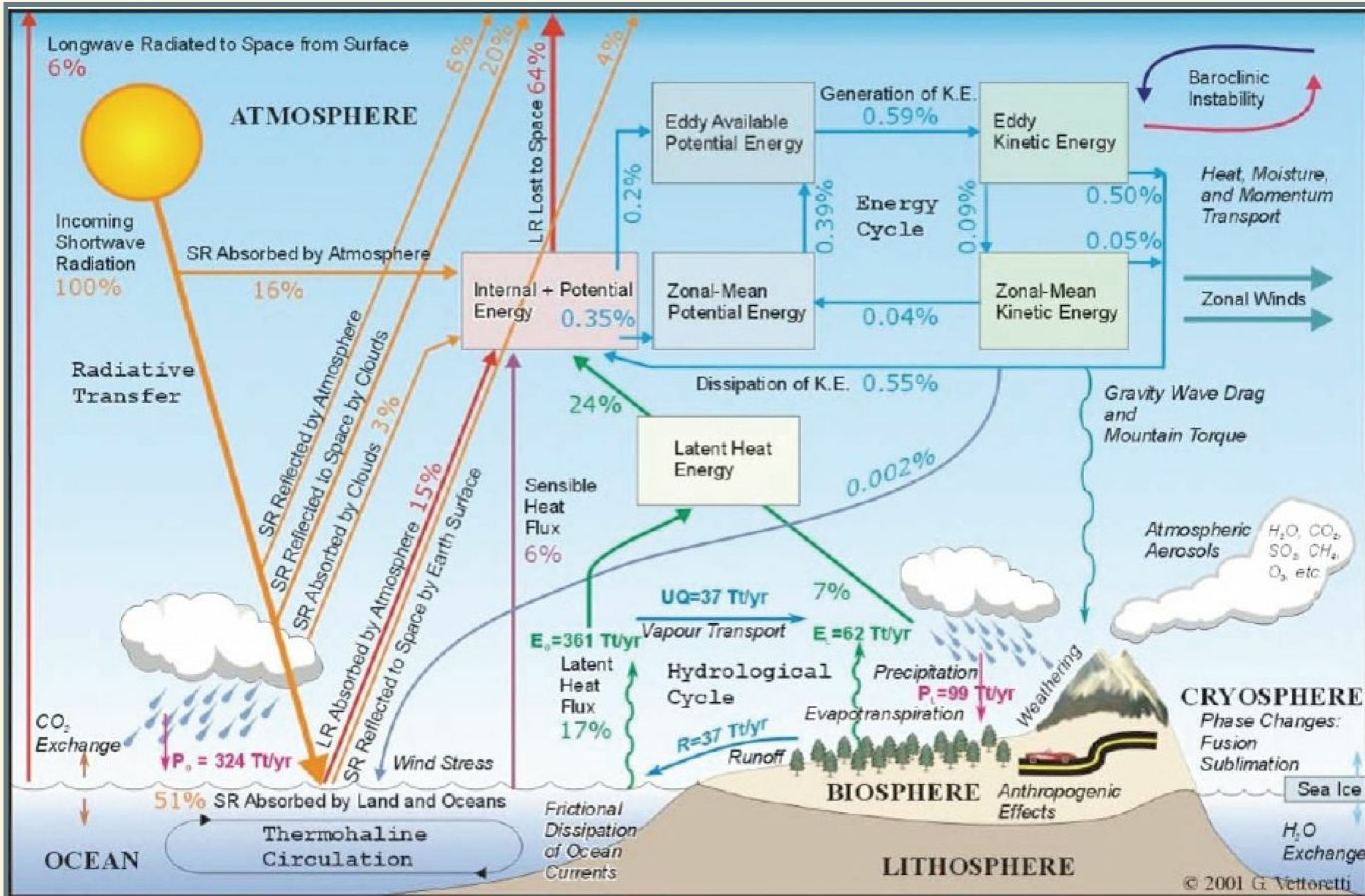
$e = E/G =$ energy intensity of economy

$f = F/E =$ $CO_2$ intensity of energy supply

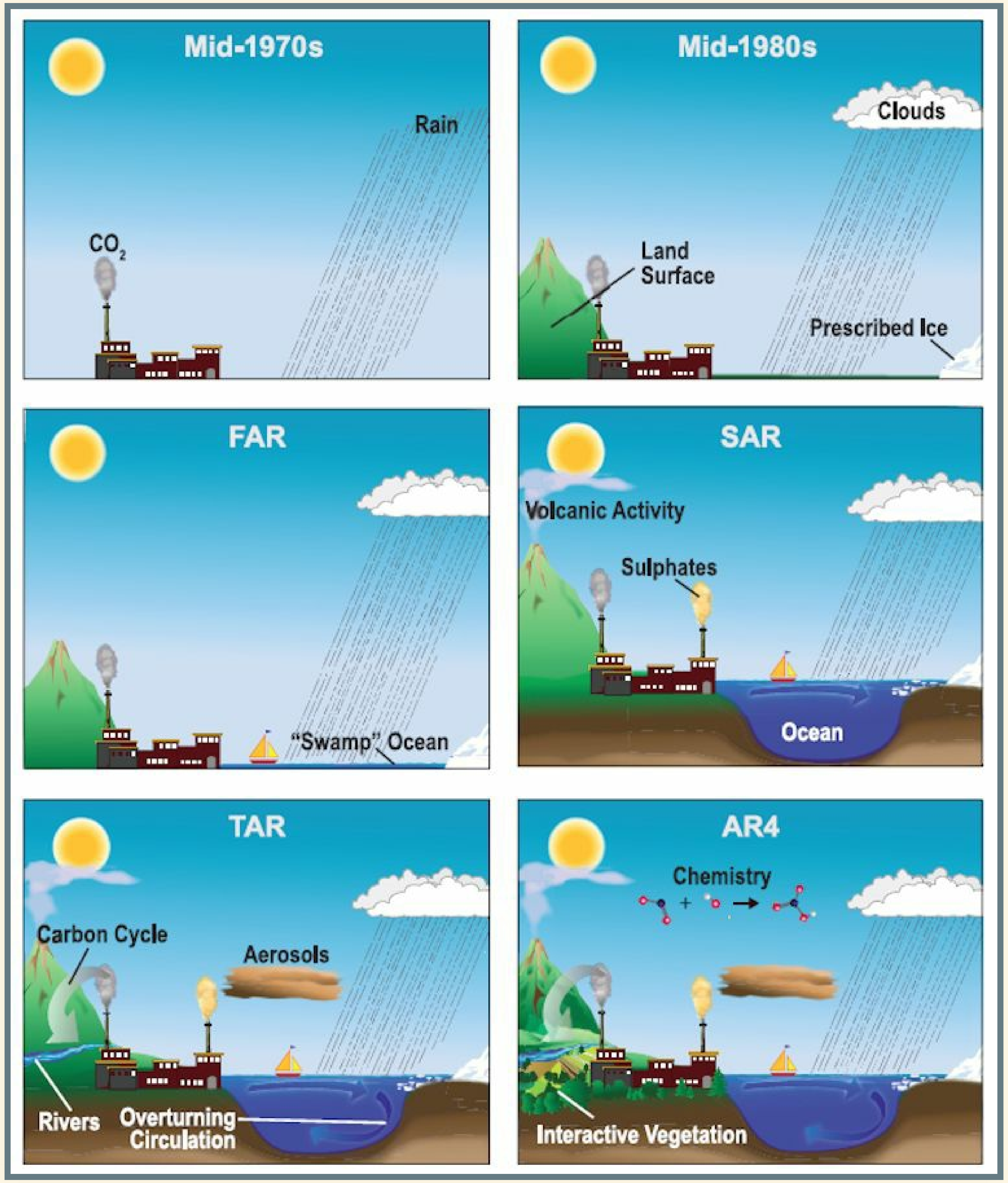
# Kaya Identity in Practice



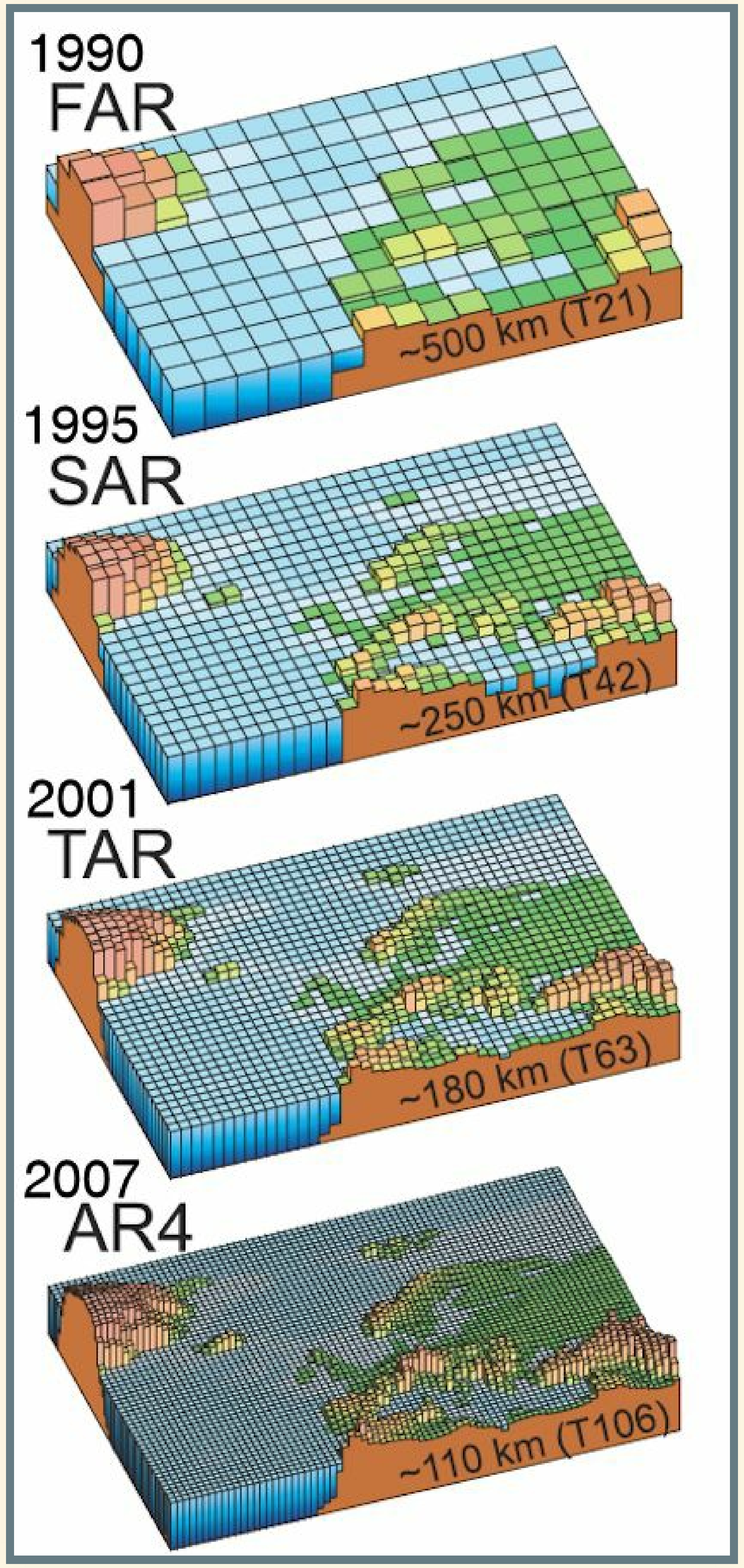
# Computer Models of Climate

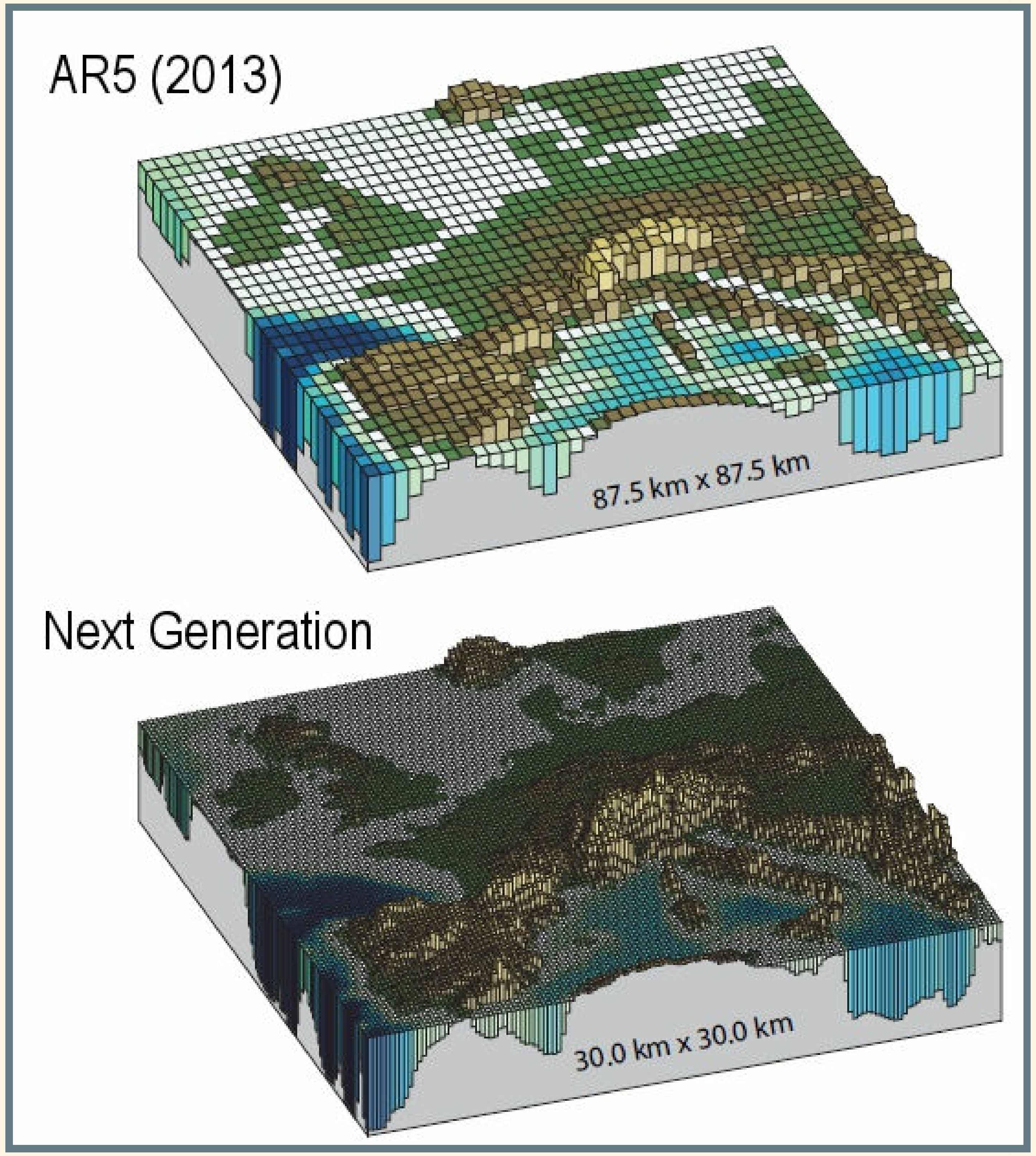


# Computer Models



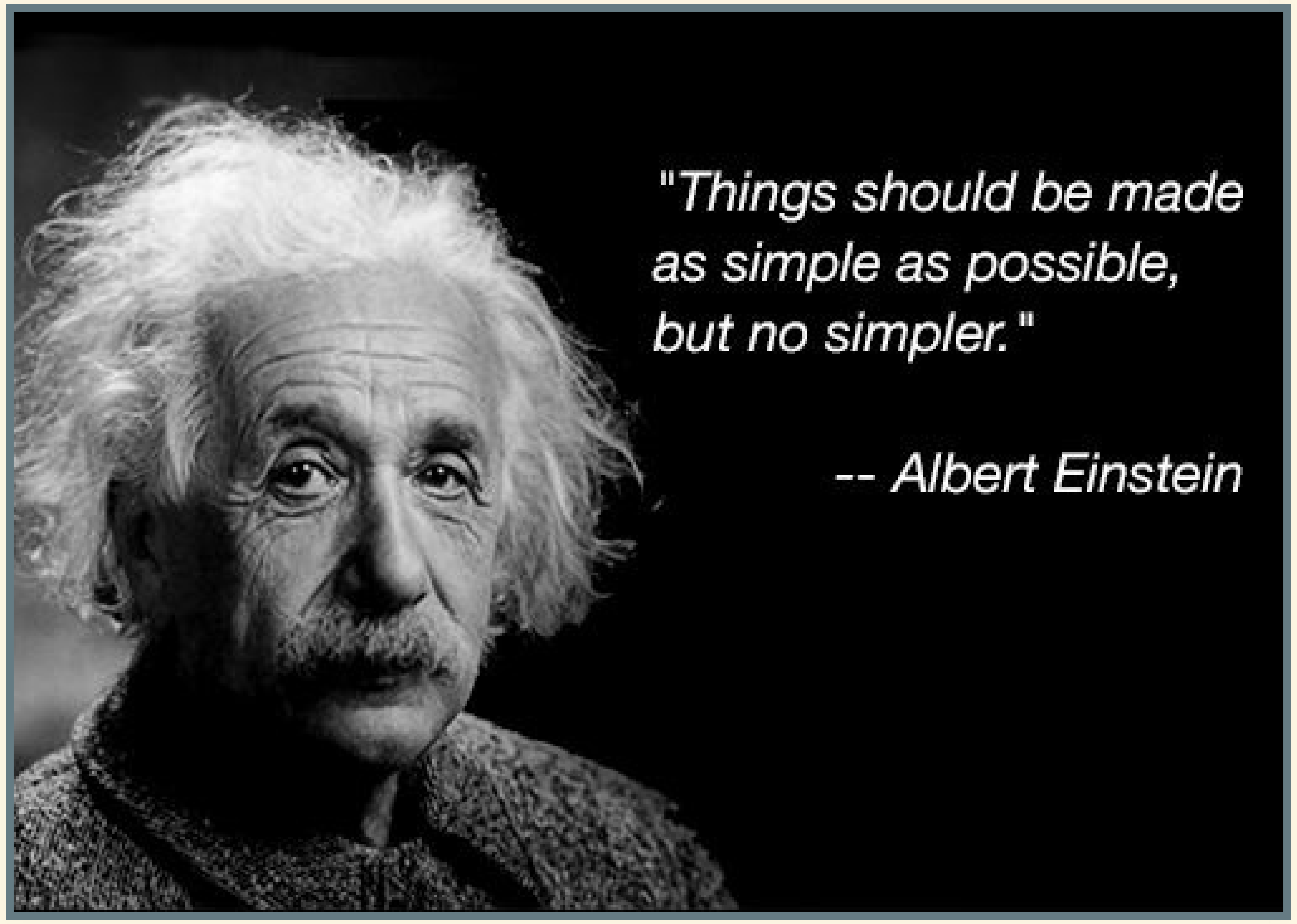
# Computer Models



# Principles of Computer Modeling

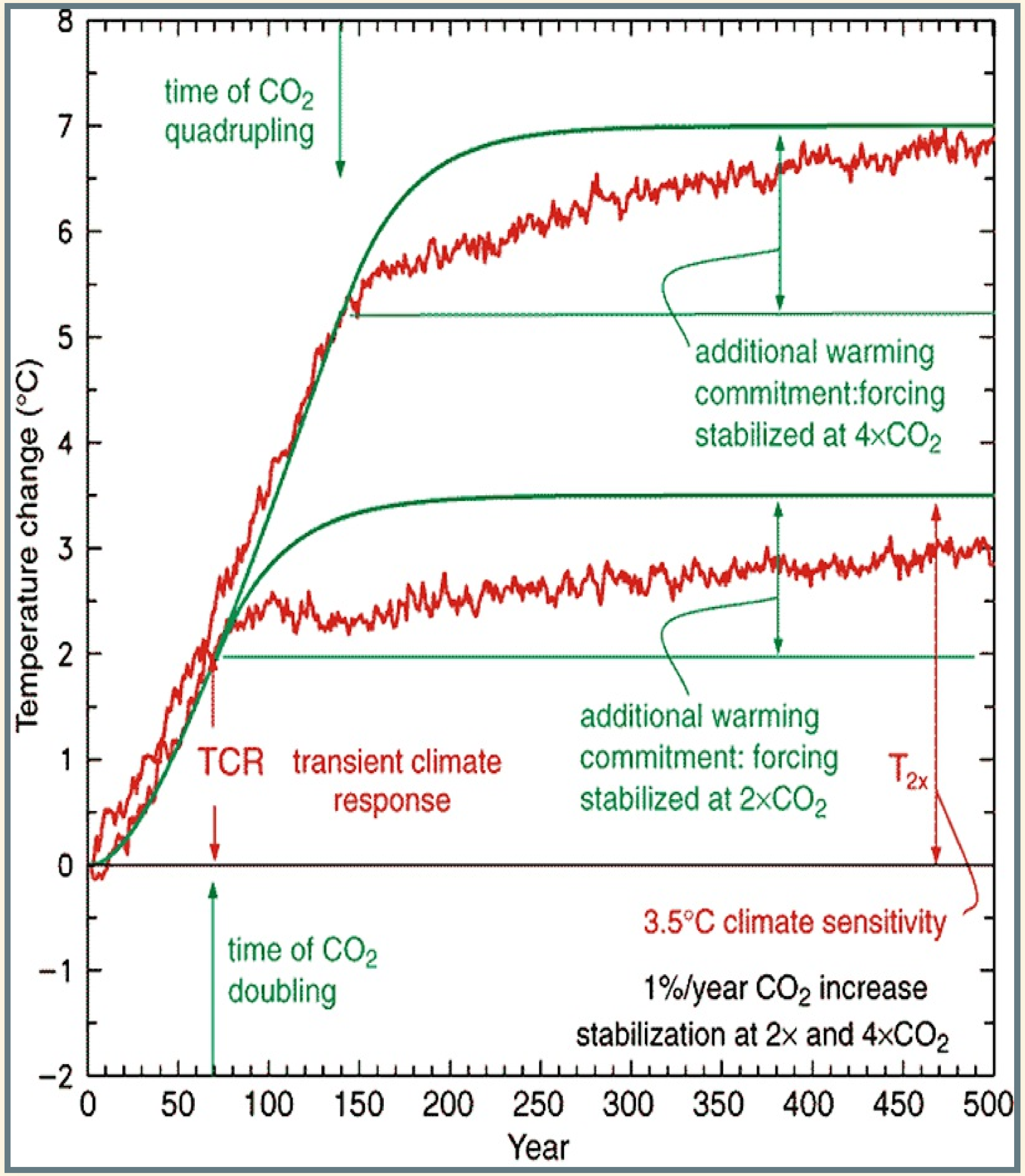
- Make models as simple as possible:
  - Start simple
  - Add complexity only as needed
    - Different models for different purposes
  - Check model against real world



# 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:
  $\Delta T$ 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 → resulting emissions
  - **Pathway**: possible future,
    - Trajectory of emissions → 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 (% per year)** |
|---|---|---|---|
| *g* ($/person) | 42,300 | 83,700 | 1.7 |
| *ef* (tons/$million) | 432 | 226 | -1.6 |
| *P* (millions) | 309 | 399 | 0.6 |
| **Total Emissions** *F* (million tons $CO_2$) | **5,640** | **7,550** | 1.7 - 1.6 + 0.6 = **0.7** |

# Projections for future world emissions:

| | 2010 | 2050 | Growth rate (% per year) |
|---|---|---|---|
| *g* ($/person) | 9,780 | 22,400 | 2.1 |
| *ef* (tons/$million) | 522 | 278 | -1.6 |
| *P* (millions) | 6,410 | 9,170 | 0.9 |
| **Total Emissions** *F* (million tons $CO_2$) | **34,900** | **57,600** | 2.1 - 1.6 + 0.9 = **1.4** |

# Uncertainties in Projections

## Projections for future world emissions:

| | **2010** | **2050** | **2100** | **Growth rate** |
|---|---|---|---|---|
| *g* | 9,780 | 22,400 | 64,737 | 2.1 |
| *ef* | 522 | 278 | 123 | -1.6 |
| *P* | 6,410 | 9,170 | 14,409 | 0.9 |
| **Emissions** | **34,900** | **57,600** | **115,366** | **1.4** |

# Uncertainties in Projections

## Projections for future world emissions with slightly different growth rates:

| | 2010 | 2050 | 2100 | Growth rate |
|---|---|---|---|---|
| *g* | 9,780 | 24,540 | 77,505 | 2.3 |
| *ef* | 522 | 298 | 148 | -1.4 |
| *P* | 6,410 | 9,563 | 15,766 | 1.0 |
| **Emissions** | **34,900** | **69,973** | **180,930** | **1.9** |
| **Difference (%)** | | **22%** | **57%** | |