Structural Modeling of the Economic Impacts of Climate Change A Peek Under the Hood

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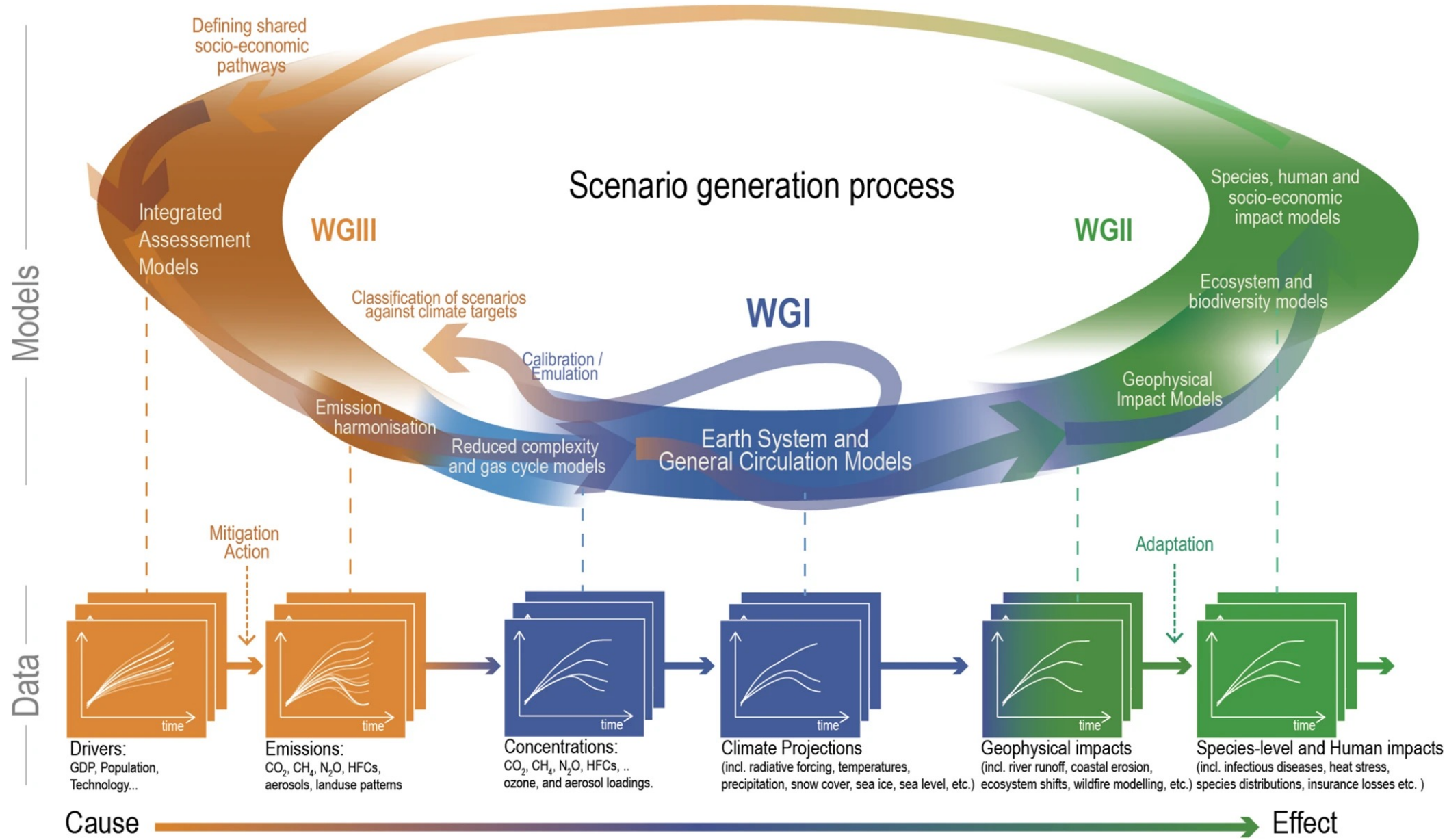

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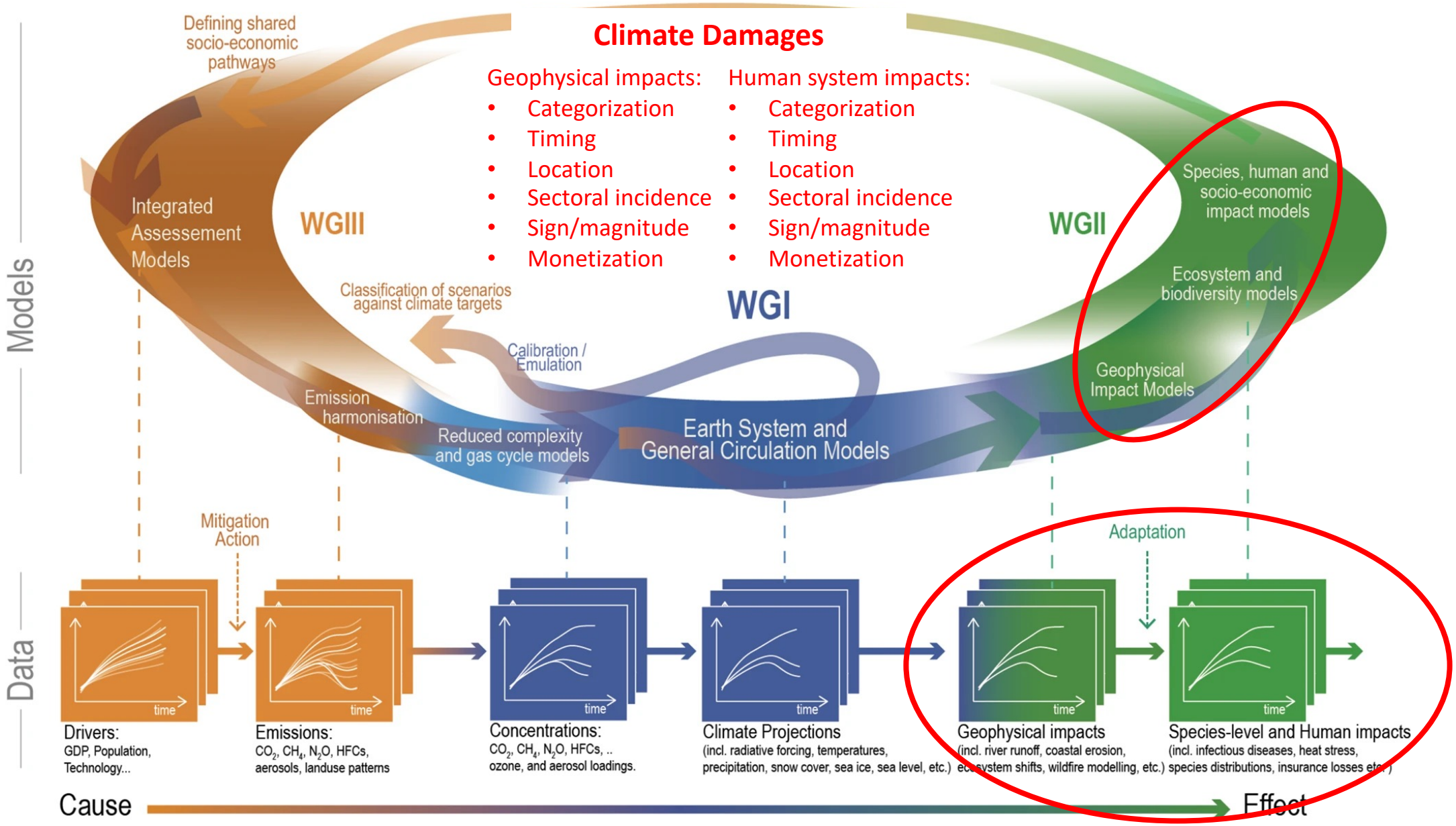

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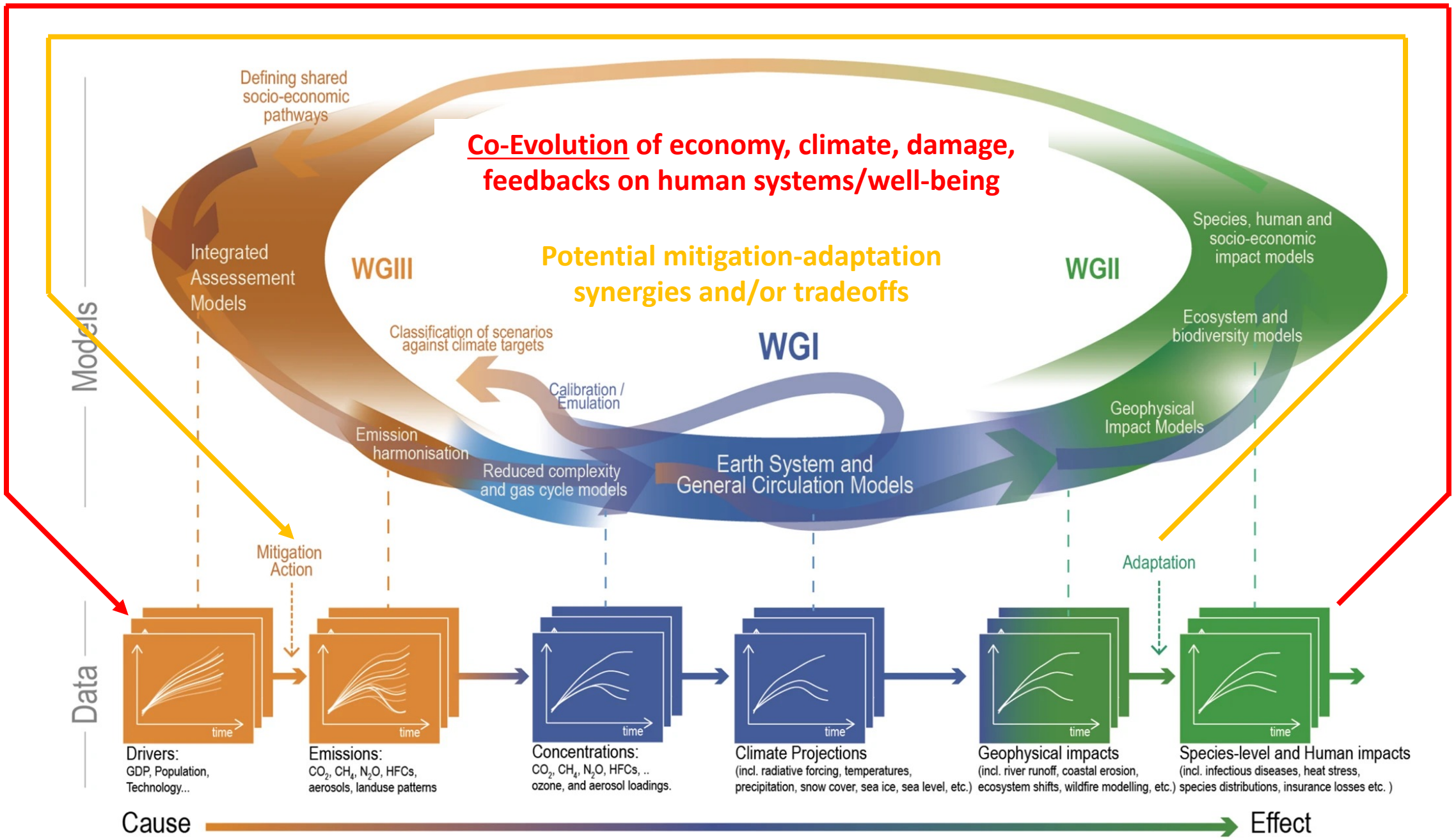

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Tightly Coupled Co-Evolution: Early Integrated Assessment Models

Aggregate Global/Regional Economy

- Population
- Production
- Consumption
- Energy use
- Well-being

Δ GDP due to climate damage

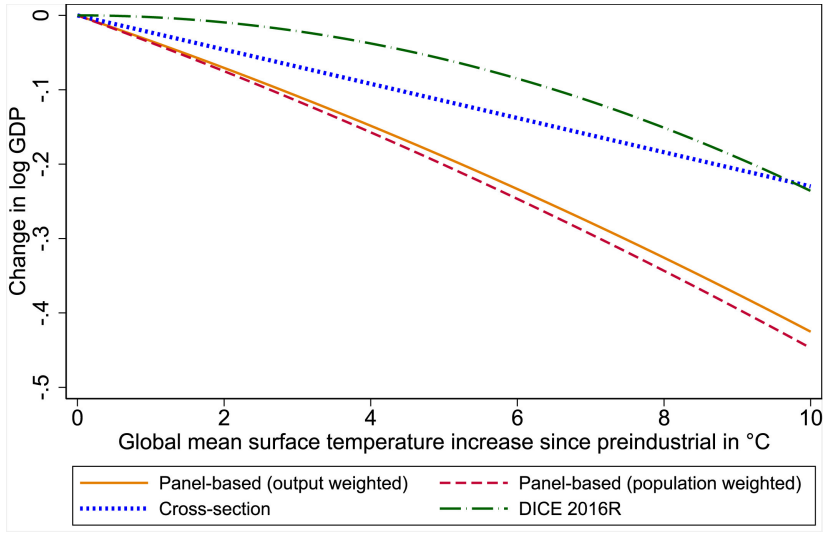
Δ Global GHG emissions

Model steps through time to simulate the future

Simplified Carbon Cycle/Climate Model

Δ Global mean temperature

Aggregate Damage Function



Tightly Coupled Co-Evolution: Early Integrated Assessment Models

Aggregate Global/Regional Economy
- Population
- Production
- Consumption
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- Well-being

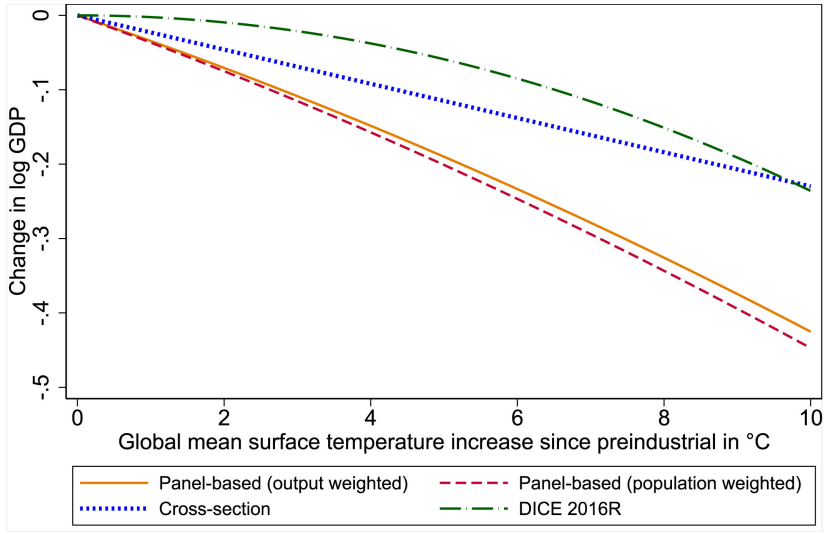
Δ GDP due to climate damage

RICE, WITCH models: regionalization

Δ Global GHG emissions

FUND model: impact categories x region

Aggregate Damage Function



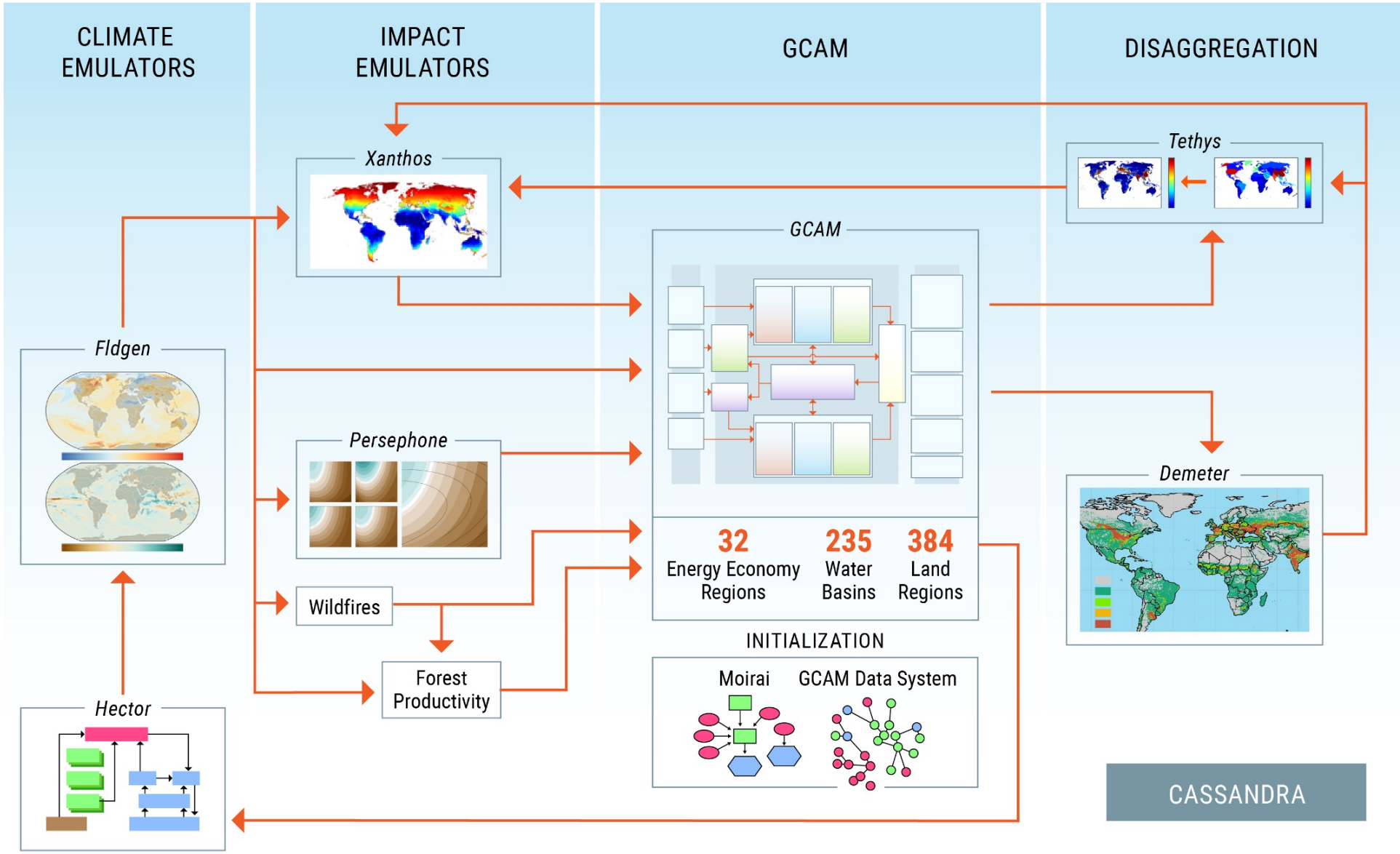
Model steps through time to simulate the future

Simplified Carbon Cycle/Climate Model

Δ Global mean temperature

Challenges
- Computational expense of simulating the evolution of the climate and geophysical drivers of impacts at the spatial/temporal scales at which damages are felt
- Empirical provenance of aggregate damage functions
- Moving beyond GDP to elaborate effects of impacts on the economy's functioning, emergent behavior, and endogenous capacity to adapt
- Complexity of system integration grows with improvements to the fidelity of individual components
- Modeling the system via forward-looking behavior is computationally intractable

Current Generation IAMs:
Global Change Intersectoral Modeling System (GCIMS)



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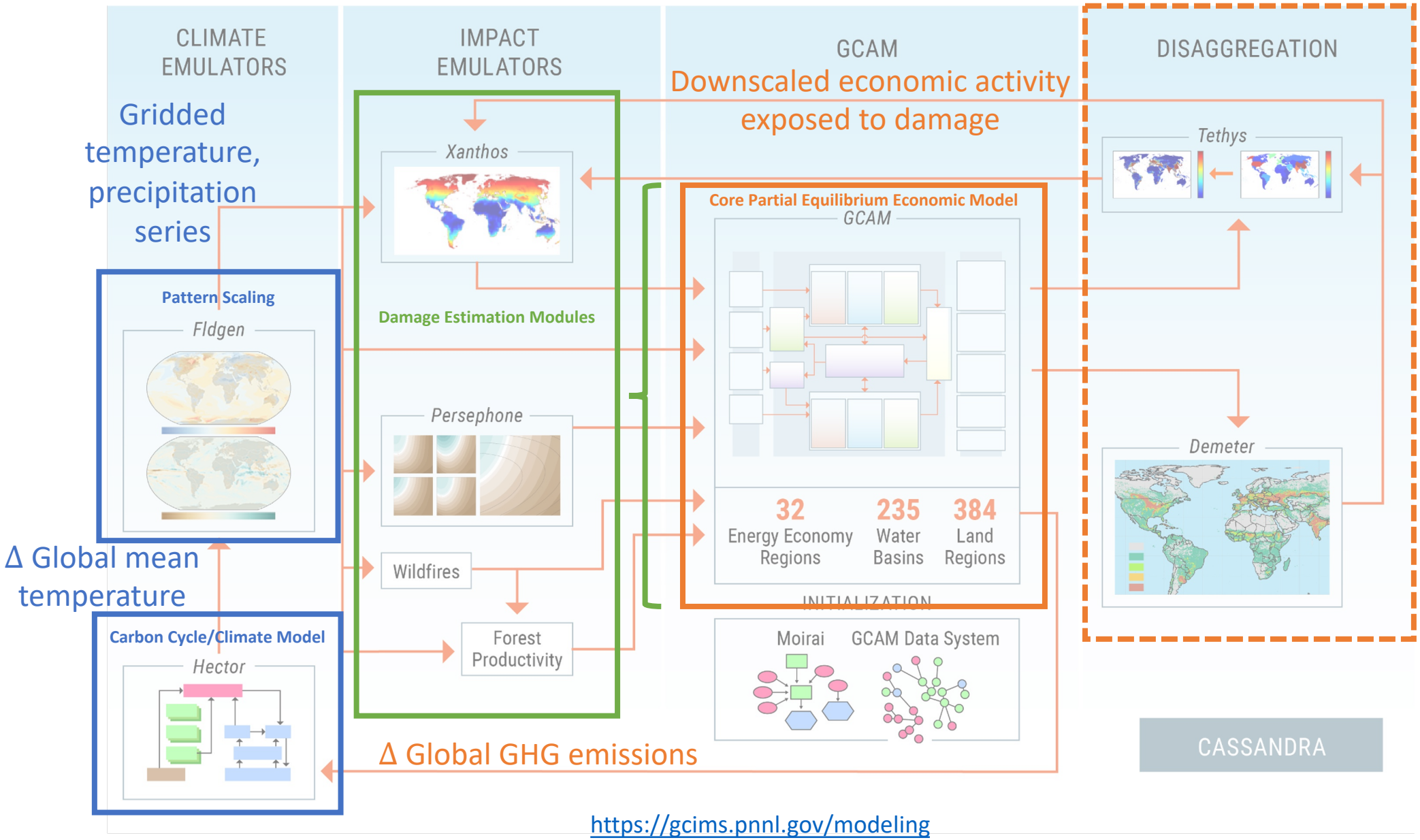

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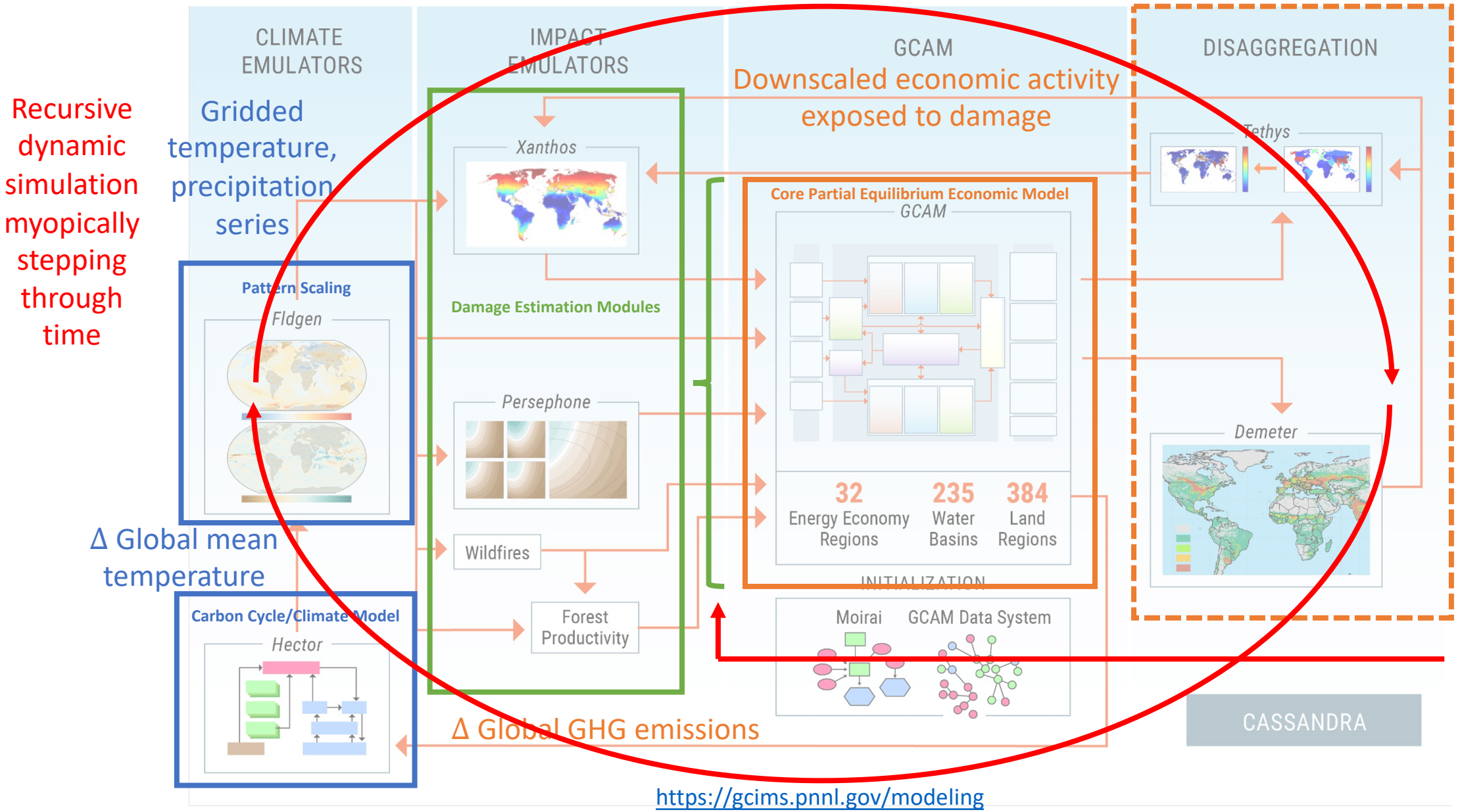

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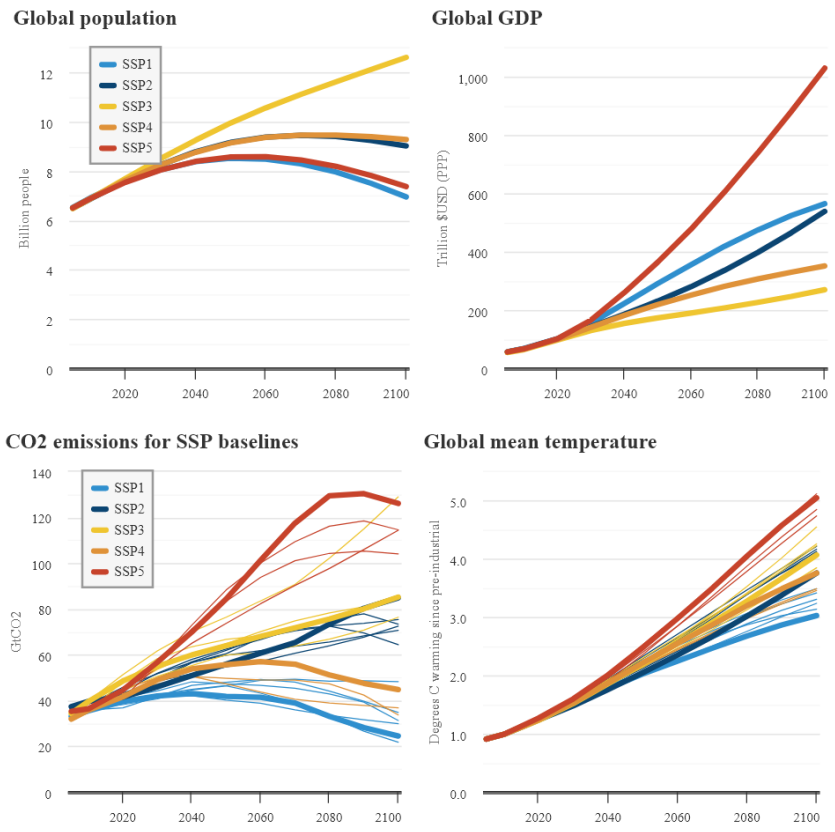
The Shared Socioeconomic Pathway (SSP) Scenarios: A Coordination Device for Division of Modeling Effort

Integrated Assessment/Economic Models

dynamics of economy, energy, GHG emissions, mitigation

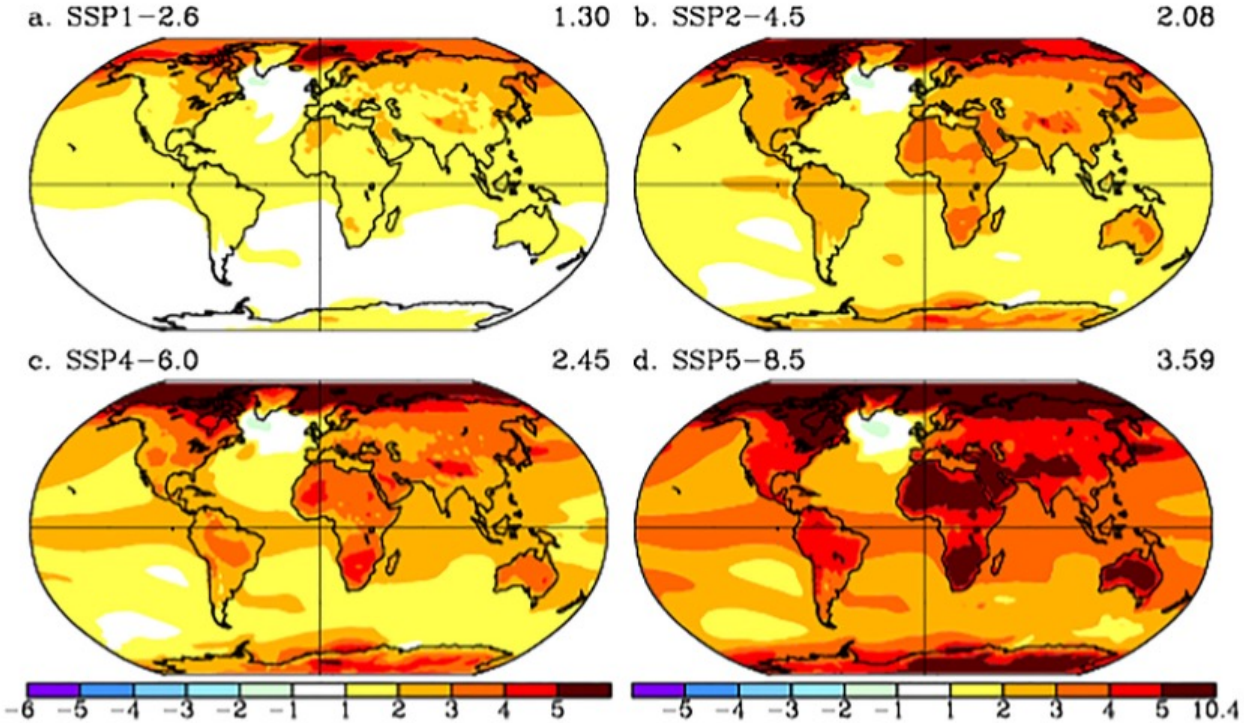


Global Climate Models

standalone computationally expensive machinery

consistent, spatially resolved changes in geophysical variables

archive outputs and use as input data to impact calculations



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https://doi.org/10.1029/2021MS002871

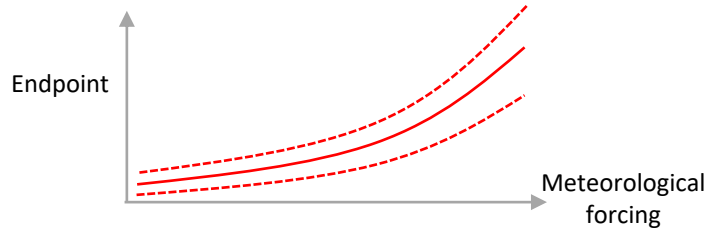
Impacts/Adaptation

Impact Observations
[endpoint x sector x place x period: can be physical or monetary units]
- Data coverage: global-scale datasets are the exception not the norm
- More common: patchwork of location-/context-specific studies

Weather Observations
- Temperature
- Precipitation
- Humidity
- Windspeed

Translation/Aggregation
- e.g., temporal/spatial averaging, binning

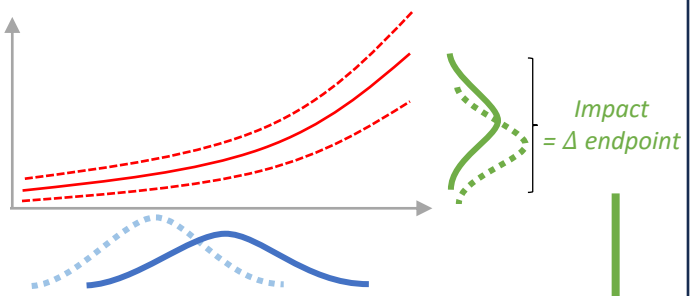
Empirical Impact Responses
- Rigorous, causally-valid estimates
- Uncertainty ⇒ transfer f'n CIs



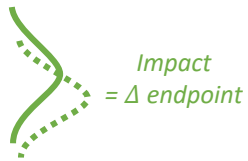
Global Climate Model Projections
[GCM x (Current climate + Future climate x SSP scenario)]
- Meteorological variables

GCM variables
⇒ Future – present Δ meteorology
Use Δ to shift observed weather
⇒ synthetic future weather

Impact Shocks/Adaptation Responses
[endpoint x sector x place x period]



Dedicated Mechanistic Process Simulations
- Computationally expensive compared to statistical emulators
- Structural system of numerically parameterized equations representing relationships among natural/ human variables
- Can be challenging to assess theoretical basis, empirical provenance of human/natural linkages, drivers of complex emergent behavior



Economic Models

Economic Modeling of Impacts/Adaptation (1)

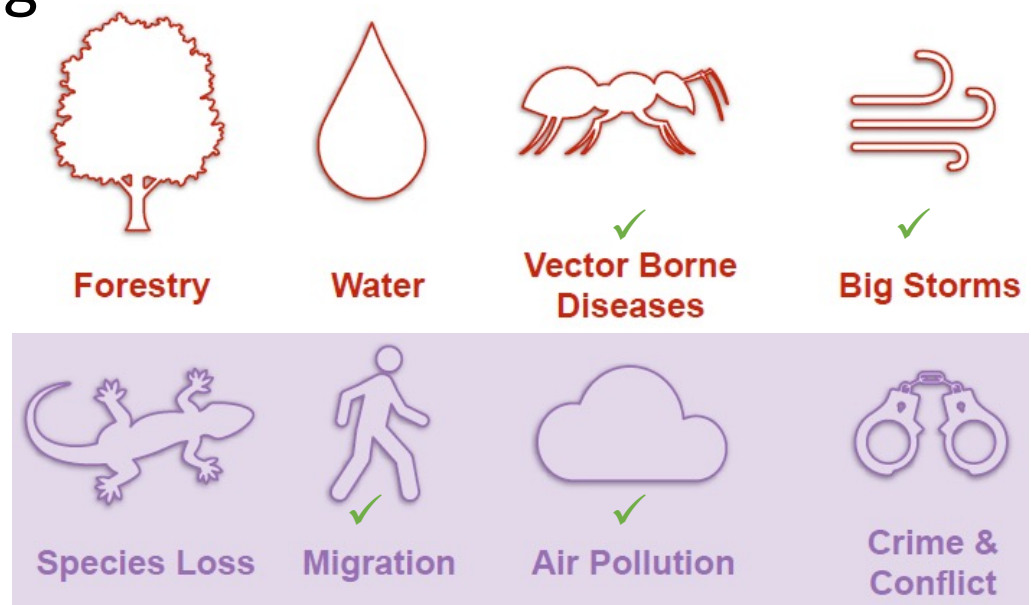
- Limited coverage of empirical studies ⇒ unavoidable extrapolation of impact responses derived for areas where impact observations are available to areas where they are not
- Much of the action is in the "buffer" through which impacts must be translated to affect the core of an economic model
  - Translators need to specify, for a particular category of impact, what kinds of activities, within what sectors of the economy, are affected, and in what ways
- Geographic/sectoral mismatch
  - For computational tractability, economic behavior in IAMs/CGE models typically aggregated to countries/multi-country regions, coarse sectoral categories
  - Necessitates spatial downscaling of activity, aggregation of fine-scale impacts
  - Sparse documentation of the details of downscaling/aggregation procedures ⇒ challenging to assess the extent to which different choices matter for aggregate estimates of damages

Economic Modeling of Impacts/Adaptation (2)

- Challenges in accounting for, and representing, adaptation
  - Empirical studies: adaptation either modeled directly or controlled for statistically
  - Process simulation studies: may or may not include different adaptation mechanisms
  - Economic models simulate input substitution, price/quantity adjustments using stylized firm production/cost and household utility/expenditure functions
  - Potential for double counting adaptations' moderating effects!
- One-way coupling ⇒ sacrifices the co-evolution captured by early IAMs (albeit in a highly stylized manner)
  - Climate change "shocks" constructed by bottom-up/empirical studies serve purely as inputs to top-down economic models
  - Economic model outputs rarely feed back on processes generating impact shocks
  - Challenging to foresee unintended consequences (e.g., the mitigation-adaptation tradeoff due to electricity consumption amplification driven by residential AC adoption as households attempt to shield themselves from worsening heat)

Economic Modeling of Impacts/Adaptation (3)

- Economic models' equilibrium solution paradigm threatens to gloss over disequilibrium impacts with potentially large attendant costs
  - Particularly important for singular extreme events: chaotic post-disaster aftermath ⇒ transitory breakdown of market functioning
- Related issue: nonmarket impacts not readily associated with categories of (market) activities captured by economic accounts, represented in production/consumption activities in models
- Lots of potential for progress characterizing mechanisms of underlying impacts, WTP
- How to aggregate these outcomes, incorporate them into economic models is at the cutting edge of research
- Whither equity: vulnerable populations at the margins of the formal economy



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