

# Integrated Assessment

## Plus a Sample Task with the MIT IGSM

**Henry D. Jacoby**

Joint Program on the Science and Policy of Global Change  
Massachusetts Institute of Technology

**Energy Modeling Forum**

**Snowmass**

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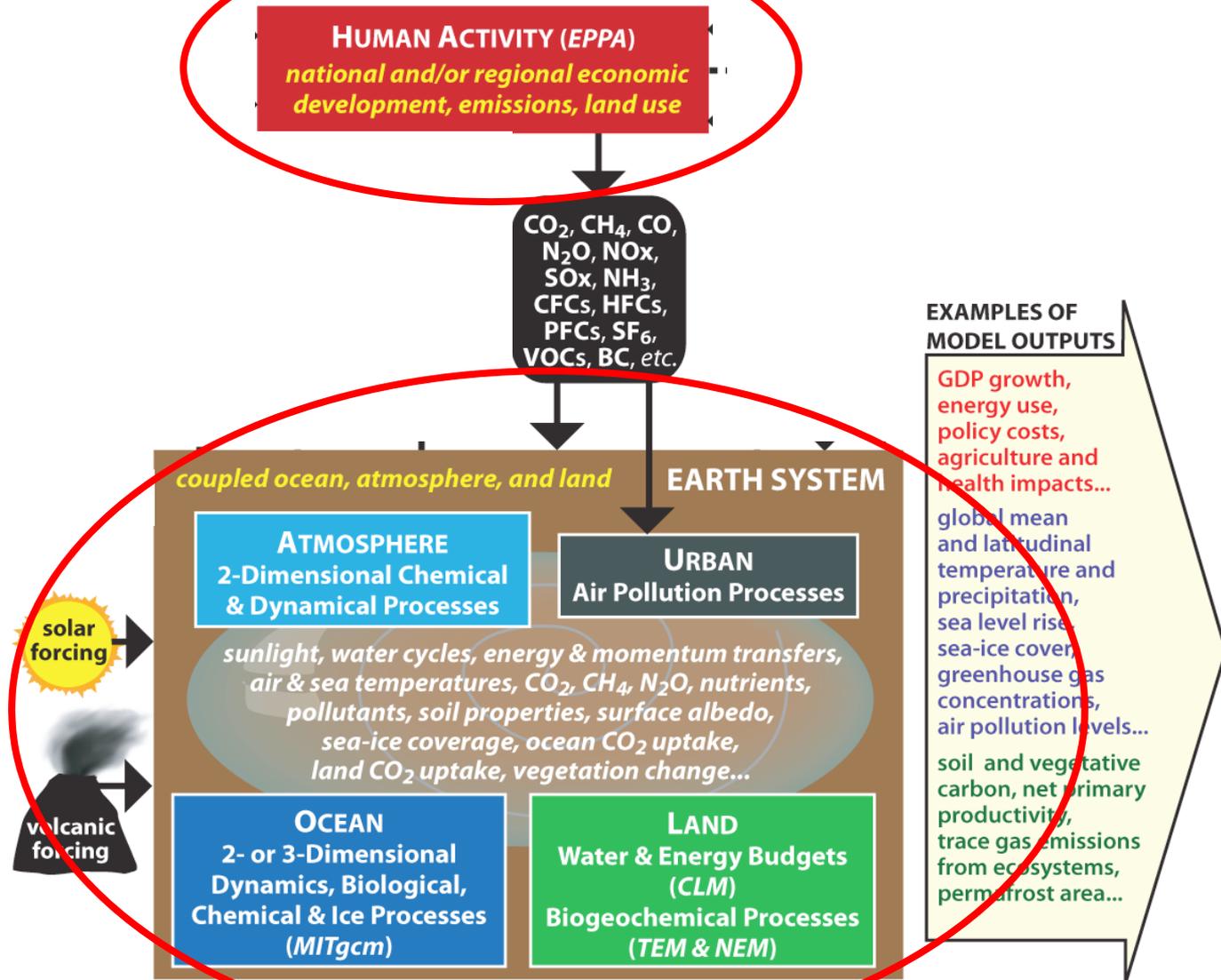
# Why Integrate? (& couple models)

- Consistency of definitions, units, etc.
- Understand & quantify interactions and feedbacks between natural & human systems
- Guide supporting research
  - Climate science issues most important for policy choice
  - Economic and policy components with greatest influence on climate & effects

# Approach Followed in Development of the MIT IGSM

- Integrate an EMIC (atmosphere, oceans, land) with multi-nation model of emissions policy cost & effects
- Seek frontiers of the science while maintaining computational efficiency for policy and uncertainty studies
- Direct the modeling and supporting research to policy-relevant issues

# Feedbacks Studied in the IGSM

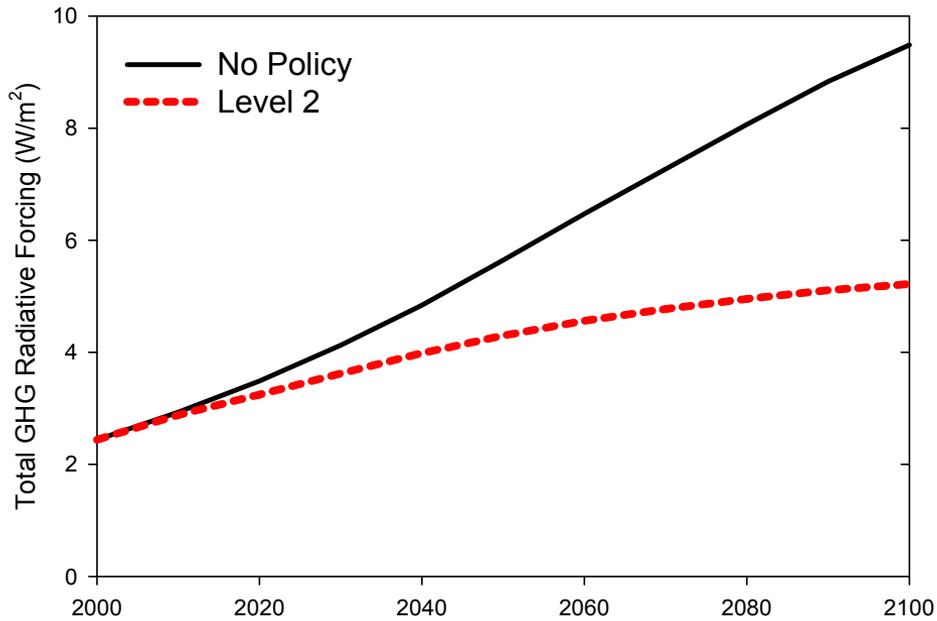


# Sample Policy Question

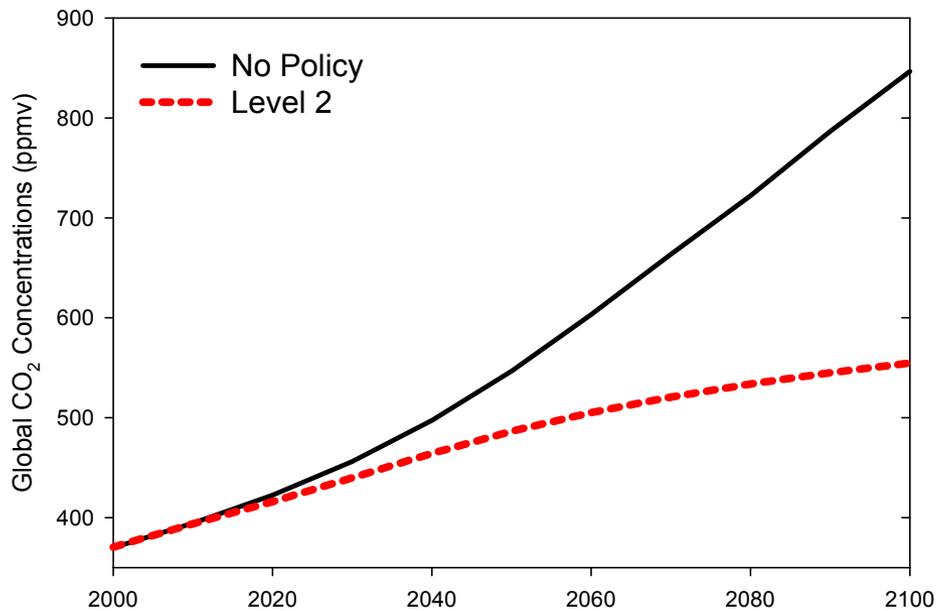
- Bali Action Plan
  - “reach an agreed . . . decision [re.] a long-term goal for emissions reductions to achieve the ultimate goal of the Convention” (i.e., GHG stabilization to avoid “danger”)
- Define goal in  $W/m^2$  or  $\Delta T$  (or  $CO_2$ -e)
- What emissions paths (& near-term levels) are consistent with any goal?
  - Scenario analysis
  - Uncertainty studies (prob. of achievement)
  - Sequential decision (hedging, etc.)

# Policy Scenarios

- Common (CCSP-style) assumption
  - Universal participation
  - When, where & what flexibility
- Differences in climate outcome for variation in the international regime?
  - Coverage of gases
    - CH<sub>4</sub> & N<sub>2</sub>O
    - O<sub>3</sub>?
  - Handling of land use and REDD
  - Partial participation

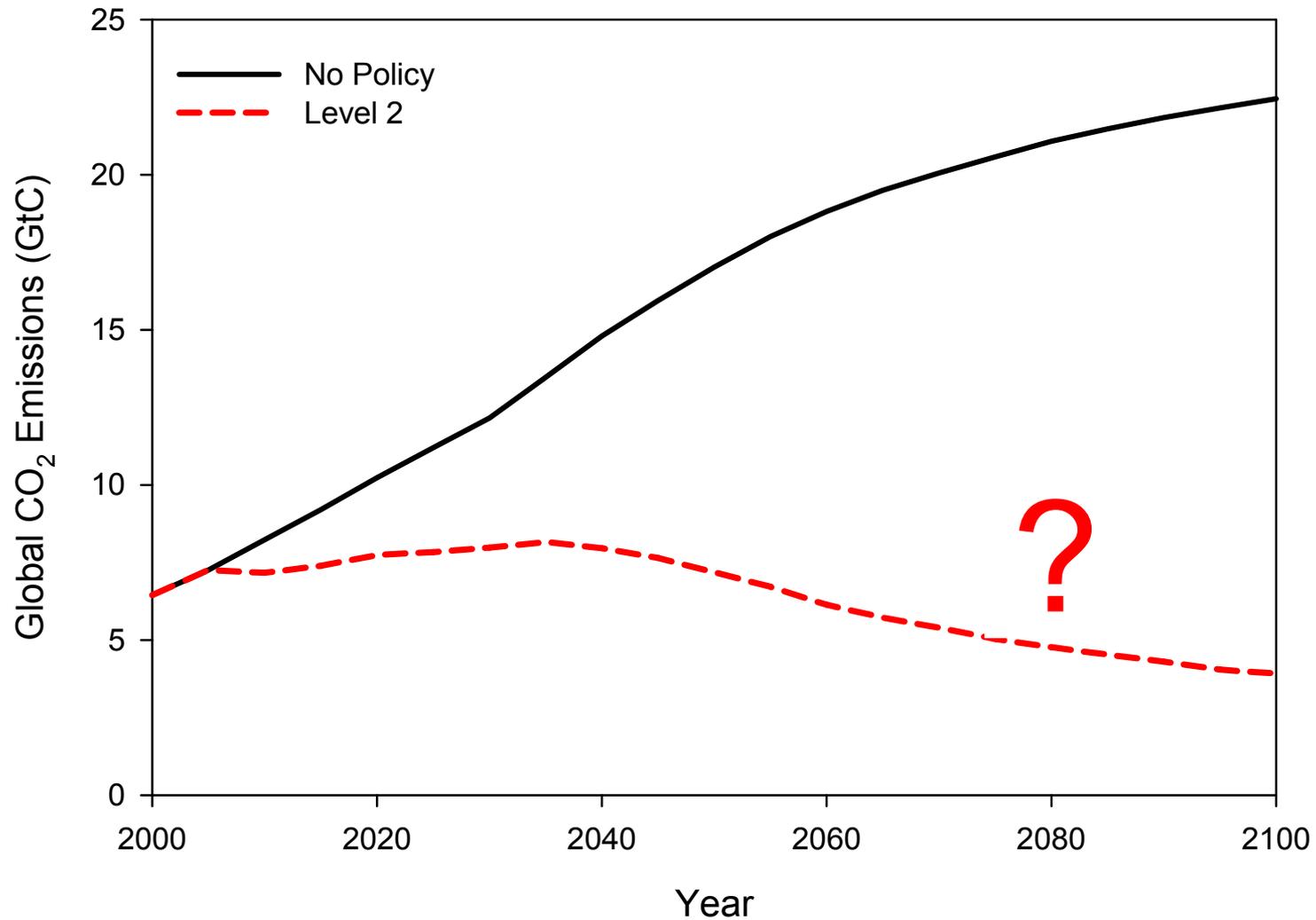


All Gas  
Radiative Forcing

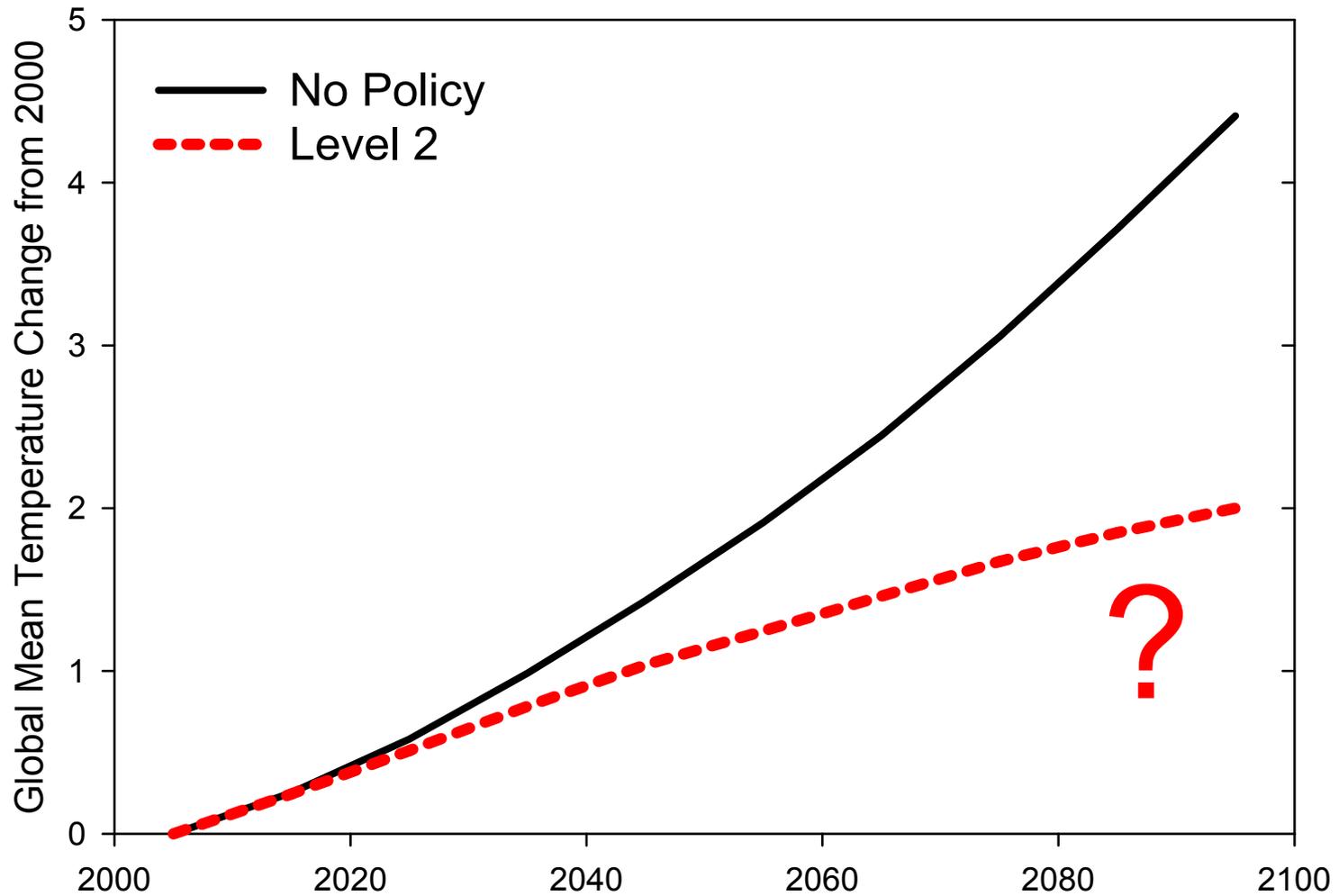


$CO_2$   
Concentrations

# Global CO<sub>2</sub> Emissions



# Global Mean Temperature Change

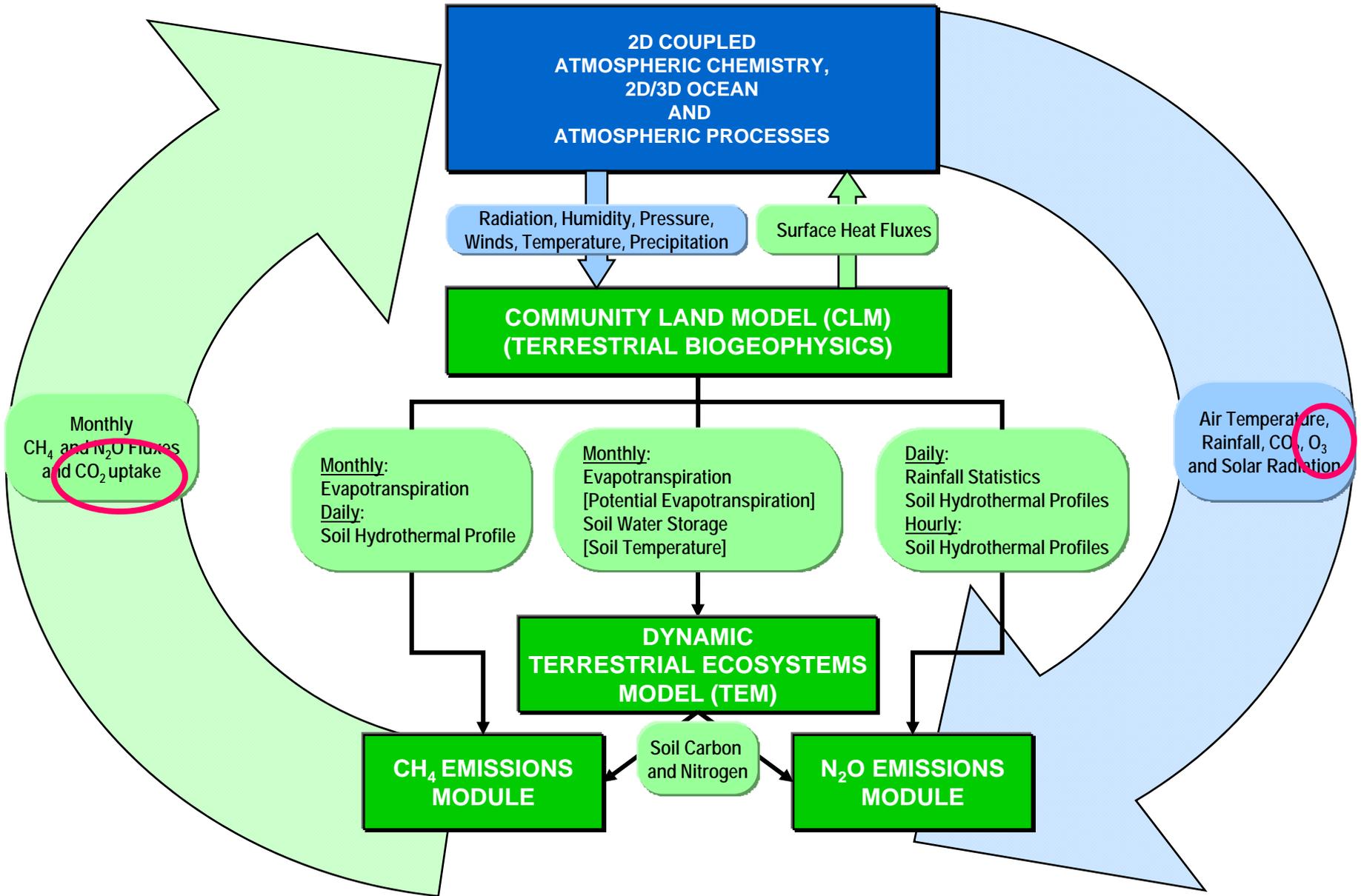


# Interactions & Feedbacks

## Influence Required Reductions

- Changing lifetime of CH<sub>4</sub>
  - Urban air pollution & controls
- Natural emissions of CH<sub>4</sub> and N<sub>2</sub>O
- Interaction with carbon cycle (e.g., O<sub>3</sub> damage, N deposition, land use change)
- Effect of mitigation policy details (for a given target) on climate outcomes
- Climate effects on economic activity

# IGSM Biogeophysical and Biogeochemical Pathways

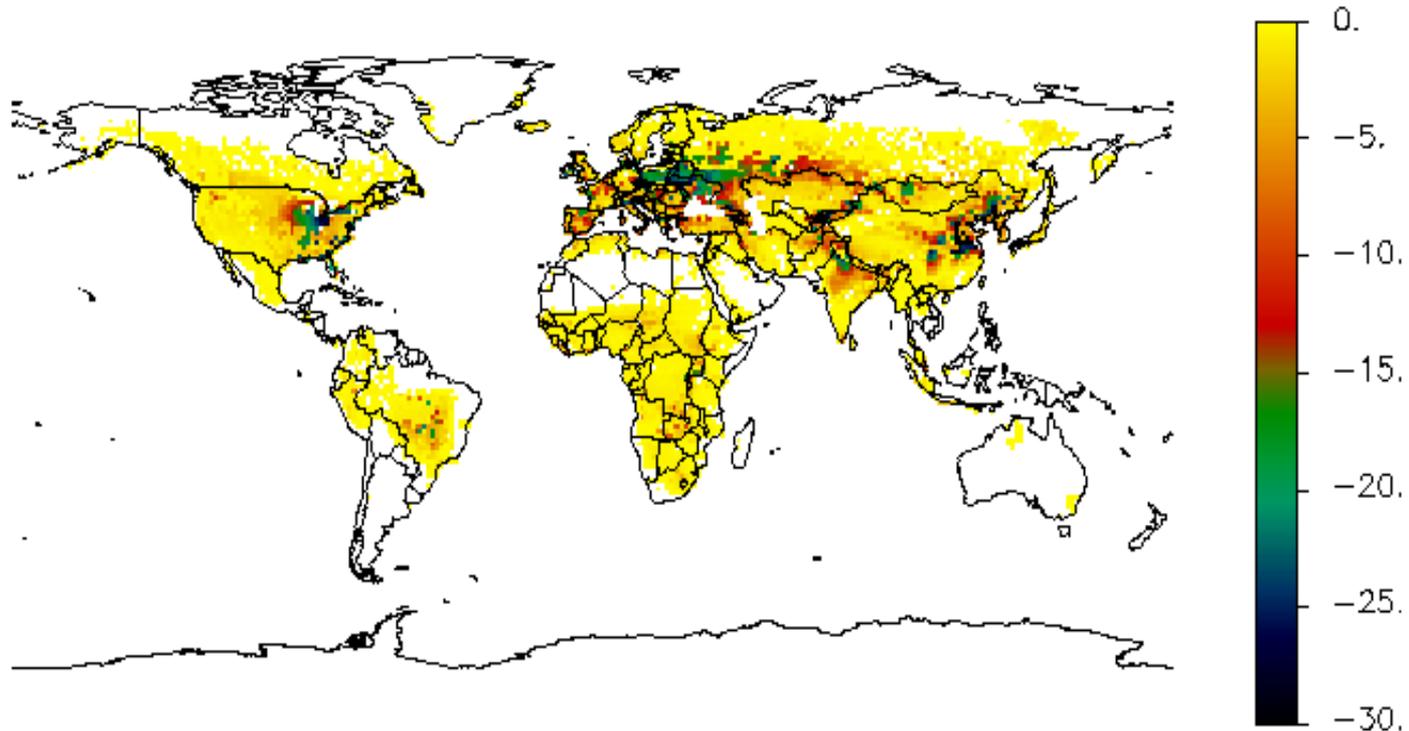


# Ozone Damage: 1989-93

Current Ozone Damage: NPP loss on Natural Ecosystems and

Annual % difference NPP (1989-1993)

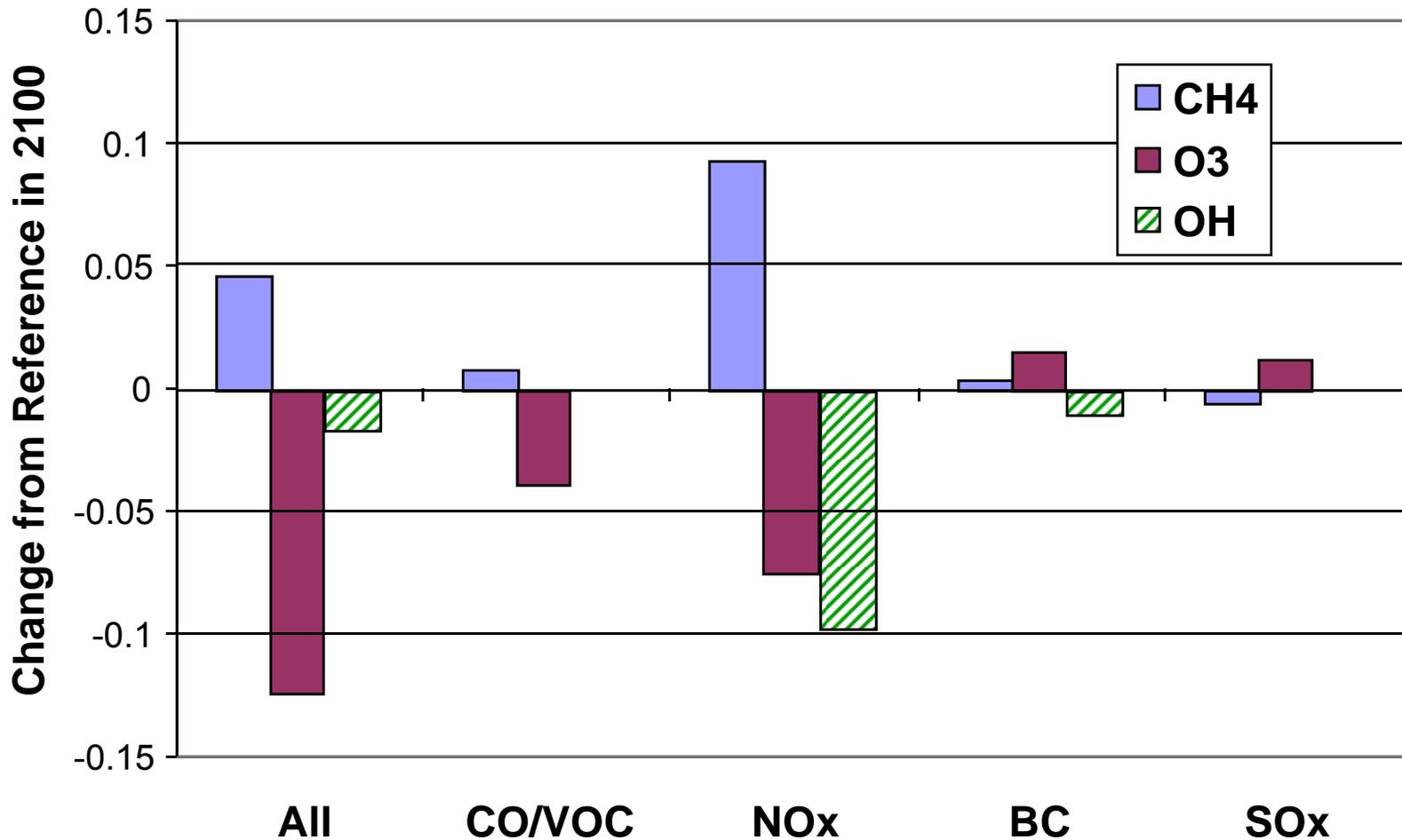
with N Fertilization



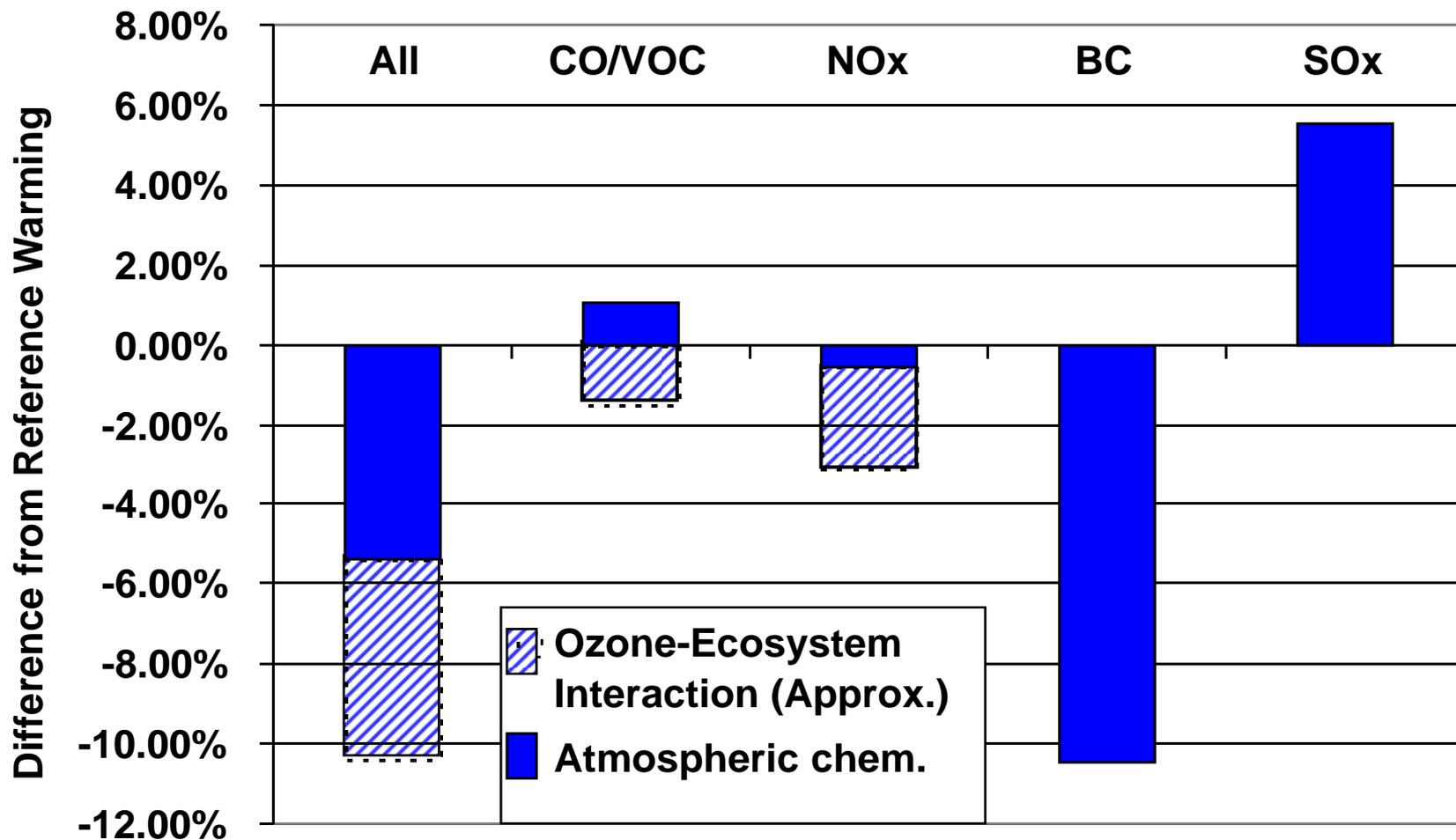
# Illustration of Chemical Interactions

- No greenhouse gas controls
- Scenarios for CO/VOC, NO<sub>x</sub>, SO<sub>x</sub>, BC
  - No additional controls
    - SO<sub>x</sub> increase of 50%
    - NO<sub>x</sub> increase of 90%
    - Other pollutants increase by 100% or so
  - Emissions held constant at 2005 levels
- Two routes of interactions through
  - Atmospheric chemistry alone
  - Terrestrial (O<sub>3</sub>) effects

# Direct impact on O<sub>3</sub> and CH<sub>4</sub> of Holding Pollution Emissions Constant at 2005



# Effect on 2100 $\Delta T$ of Holding Pollution Emissions Constant



# Policy Scenarios

- Common (CCSP-style) assumption
  - Universal participation
  - When, where & what flexibility
- Differences in climate outcome for variation in the international regime?
  - Coverage of gases
    - CH<sub>4</sub> & N<sub>2</sub>O
    - O<sub>3</sub>
  - Handling of land use and REDD
  - Partial participation

# Other Examples

## (Same policy domain)

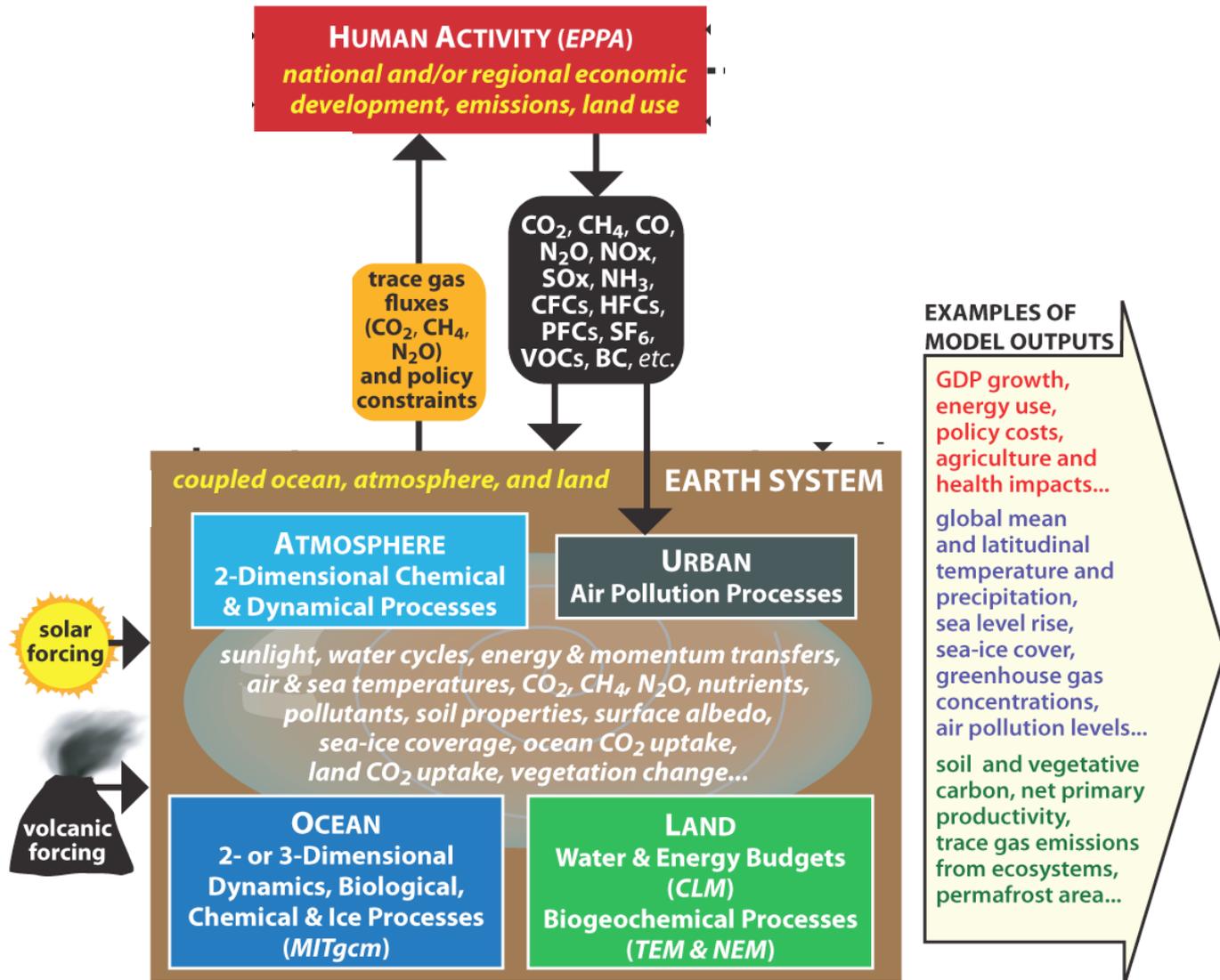
- Analysis of climate change risk & the risk-lowering effects of mitigation targets
- Analysis of sequential decision
- Analysis of renewables at large scale
  - Wind & solar
  - Biomass
- Interaction of climate with other issues
  - Water resources
  - Urban/regional pollution control
- Adaptation under different targets

# Projection: Included Uncertainties

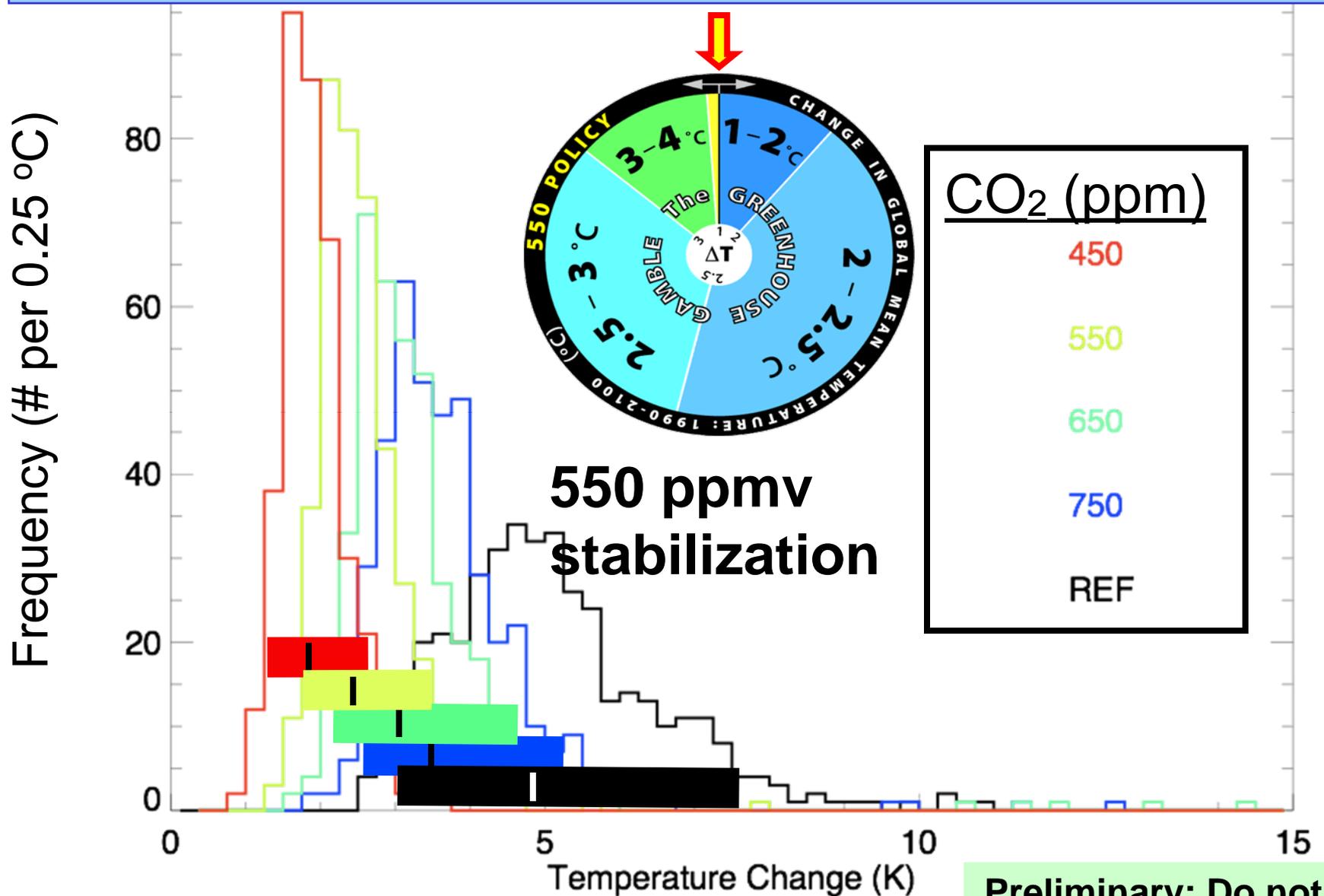
- Emissions uncertainty (from EPPA model)
- Climate system response (20<sup>th</sup> C data)
  - Climate sensitivity
  - Rate of deep ocean circulation
  - Net aerosol forcing
- Carbon cycle uncertainty:
  - Rate of carbon uptake by the deep-ocean
  - CO<sub>2</sub> fertilization effect on ecosystems
- Effect of precipitation frequency on natural emissions of CH<sub>4</sub> + N<sub>2</sub>O

X00 member  
ensembles

# Formulation for Uncertainty Studies

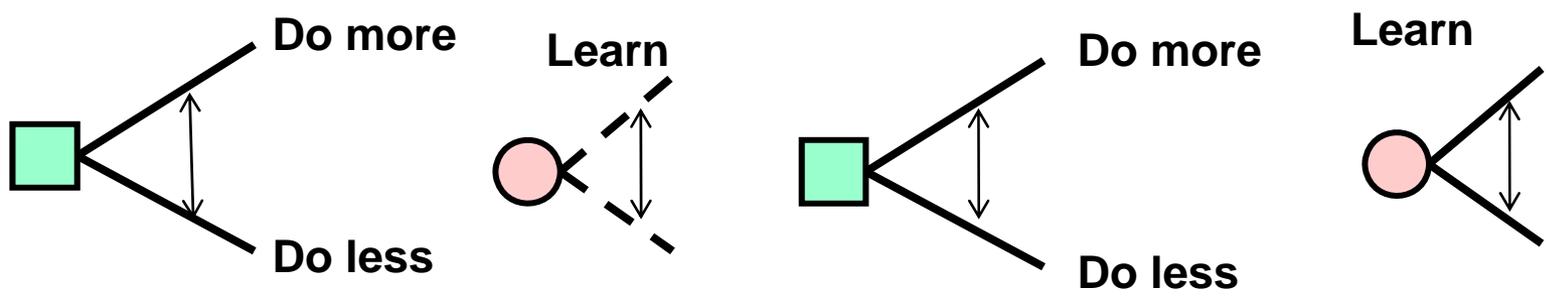
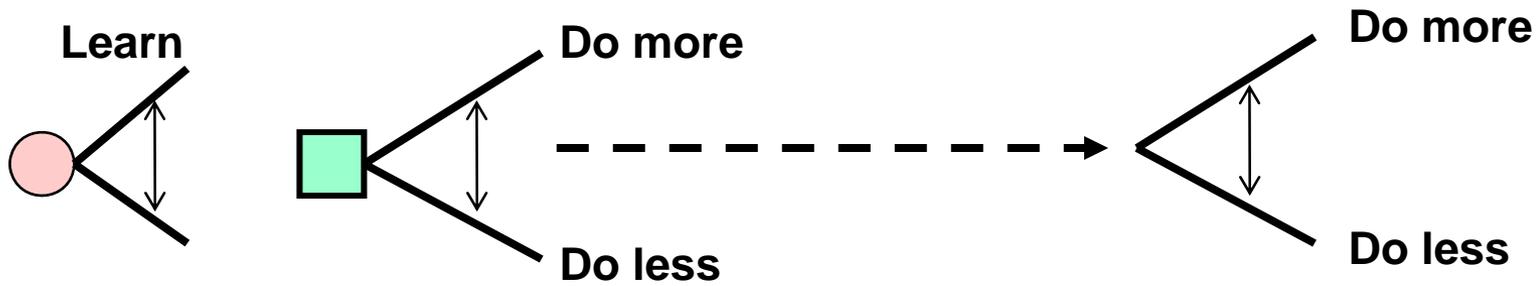


# Frequency Distributions for Temperature Change, 2000 to 2100, under No Policy and Stabilization Scenarios



Preliminary: Do not cite

# Alternative Decision Formulations



# Other Examples

## (Same policy domain)

- Analysis of climate change risk & the risk-lowering effects of mitigation targets
- Analysis of sequential decision
- Analysis of renewables at large scale
  - Wind & solar
  - Biomass (Reilly summary, if time)
- Interaction of climate with other issues
  - Water resources
  - Urban/regional pollution control
- Adaptation under different targets

# Thank You!

For more on these analyses, see  
[web.mit.edu/globalchange/](http://web.mit.edu/globalchange/)

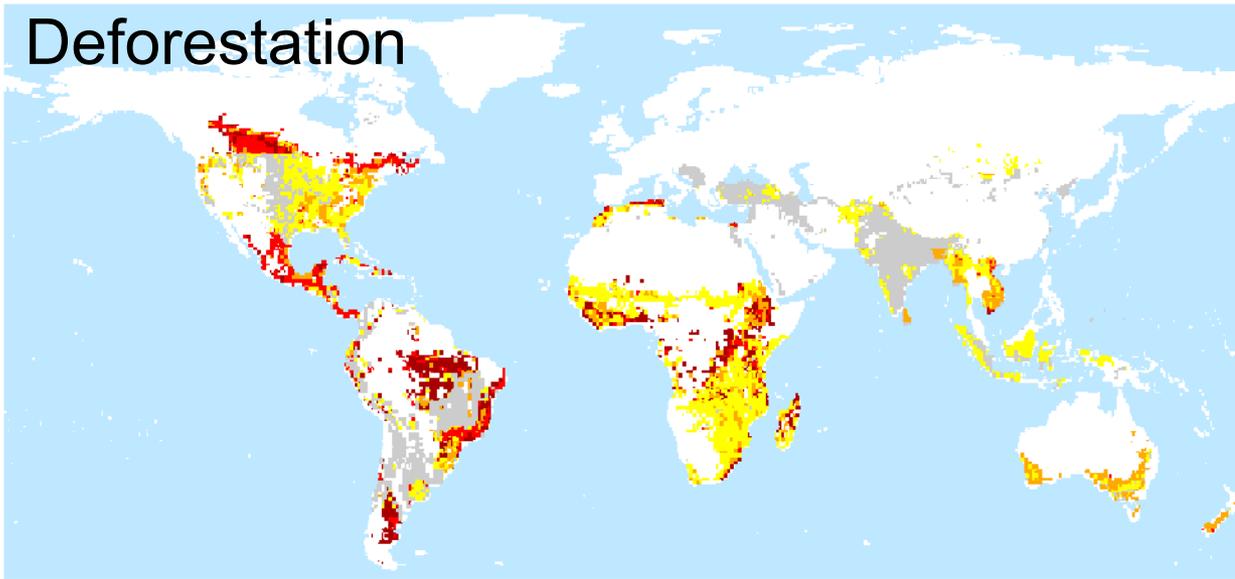
# Economics of Land Use Change

- Response to new demand (e.g., biofuels)
  - Extensive margin: convert new land
  - Intensive margin:  $\Delta$  inputs on existing land
- Expect change on both margins
  - Ease/cost & institutional barriers to conversion vs. ease of intensifying? (Will test assumptions)
- Carbon implications of biofuels
  - Energy to improve land, grow crop, process
  - Change in carbon stock on land: loss with conversion & gain from intensive management
- Biofuels may not be grown just on converted land, but may produce ripple effect
  - Soybeans to grazing land
  - Grazing to forest or unmanaged grass land

# Impacts-Adaptation Framework

- Five land types
  - Cropland, pasture, natural grassland harvested forest & natural forest
- Crops, biofuels compete for cropland
  - Pasture/m'ged forest ➔ livestock & forestry
  - Value of natural grassland & forest enters in the utility function of the representative consumer
- Land conversion to biofuels
  - Inputs to clearing, development & access  $\geq \Delta$  land rent in natural vs. biofuels use
  - Conversion of forest produces lumber
- Climate, CO<sub>2</sub> & O<sub>3</sub> affect productivity

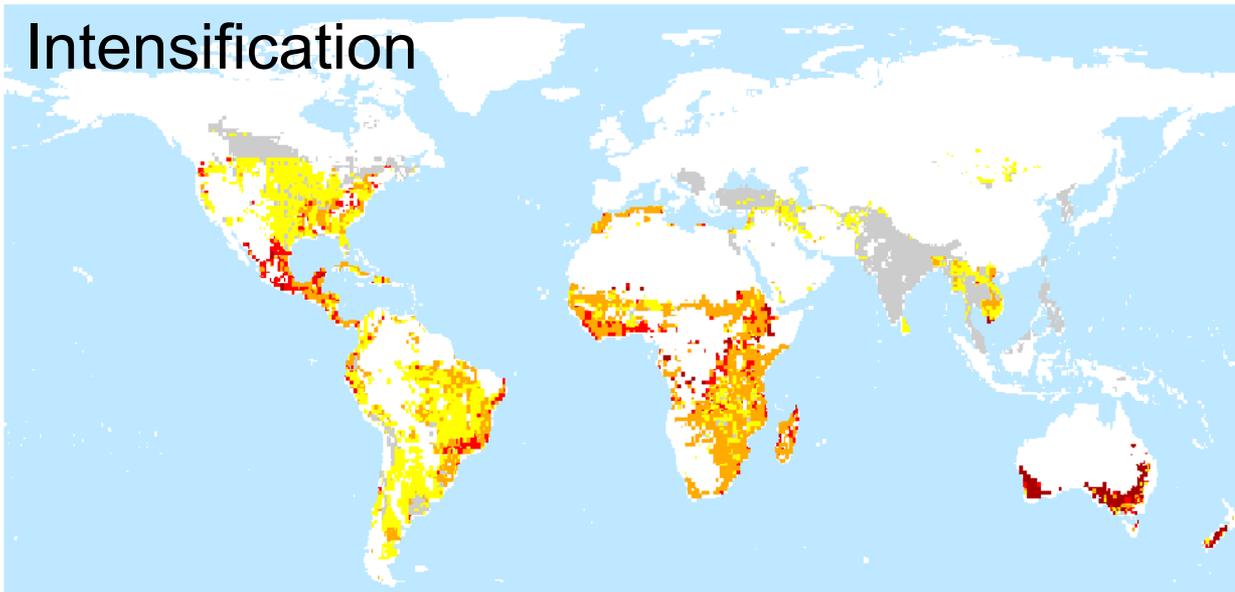
## Deforestation



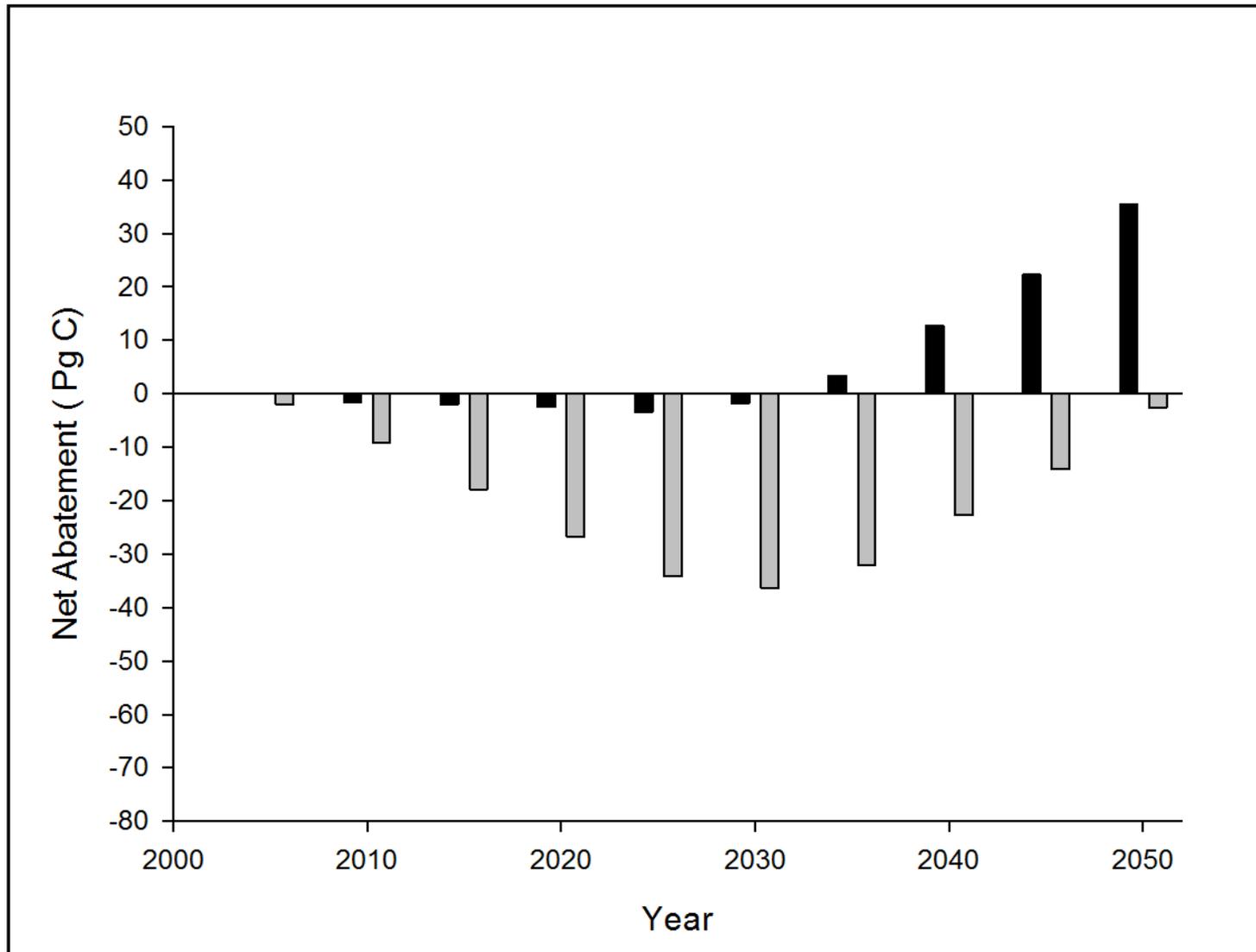
Distribution  
of  
cellulosic  
biofuels



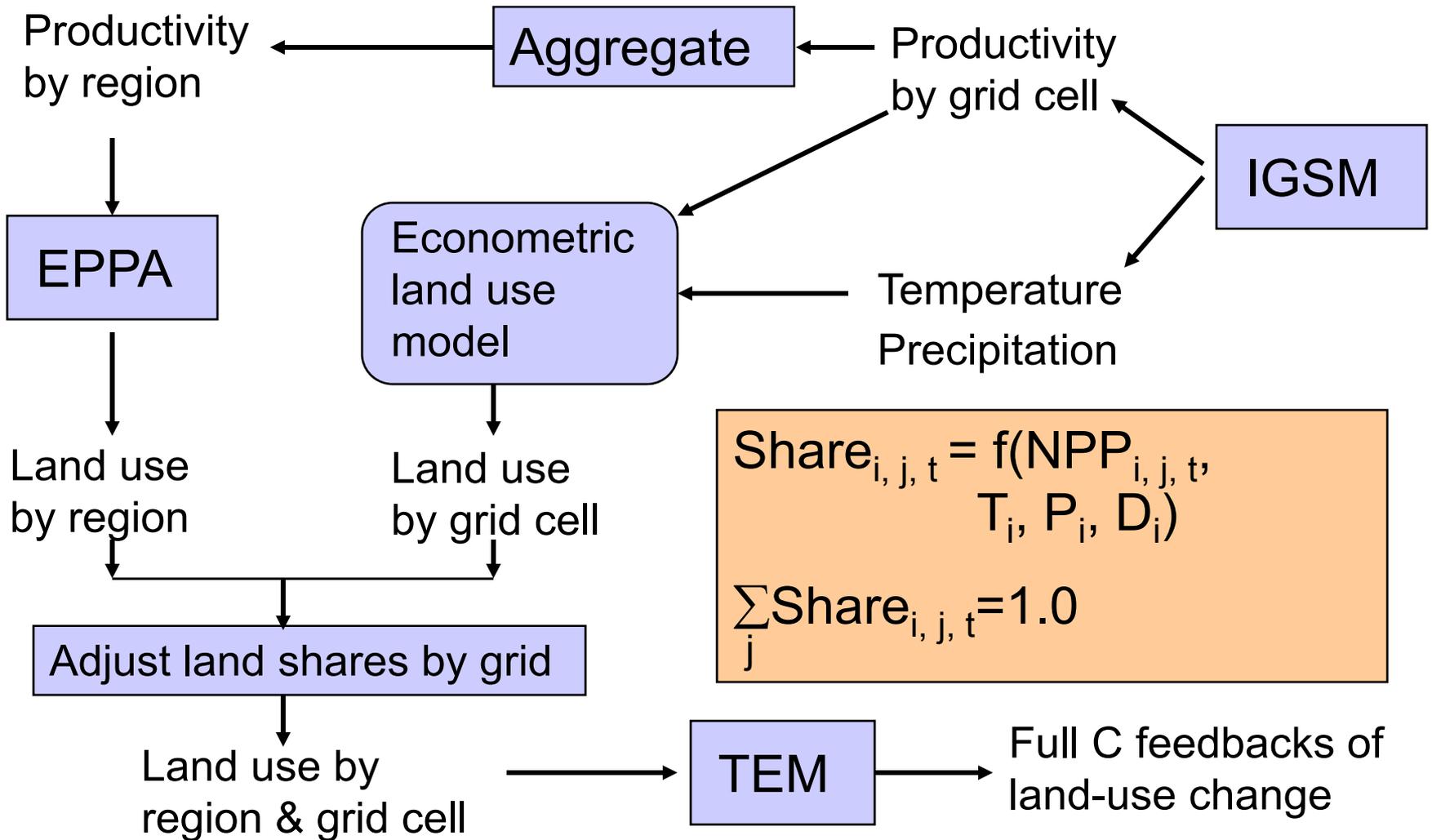
## Intensification



# Carbon Balance: Intensification



# Land-Productivity Simulation



# Sectoral Aggregation

## Sectors

### Non-Energy

Agriculture  
Energy Intensive  
Other Industry  
Services  
Industrial Transport  
Household Transport

### Energy

Crude & Refined oil,  
Biofuel  
Shale oil  
Coal  
Natural gas  
Synthetic gas (from coal)  
Electricity

For special studies  
Crude sources & gasoline, diesel, petcoke heavy oil, biodiesel, ethanol, NGLs & explicit upgrading

For special studies

Crops  
Livestock  
Forestry  
Food processing

Technologies Included

Fossil (oil, gas & coal)  
IGCC with capture  
NGCC with capture  
NGCC without capture  
Nuclear  
Hydro  
Wind and solar  
Biomass

# Regional Aggregation

## **Annex B**

**USA**

**Europe**

**Canada**

**Mexico**

**Japan**

**Aus. & N.Z.**

**FSU**

**E. Europe**

## **Non-Annex B**

**China**

**India**

**Persian Gulf**

**Indonesia**

**Africa**

**Latin America**

**East Asia**

**Rest of World**