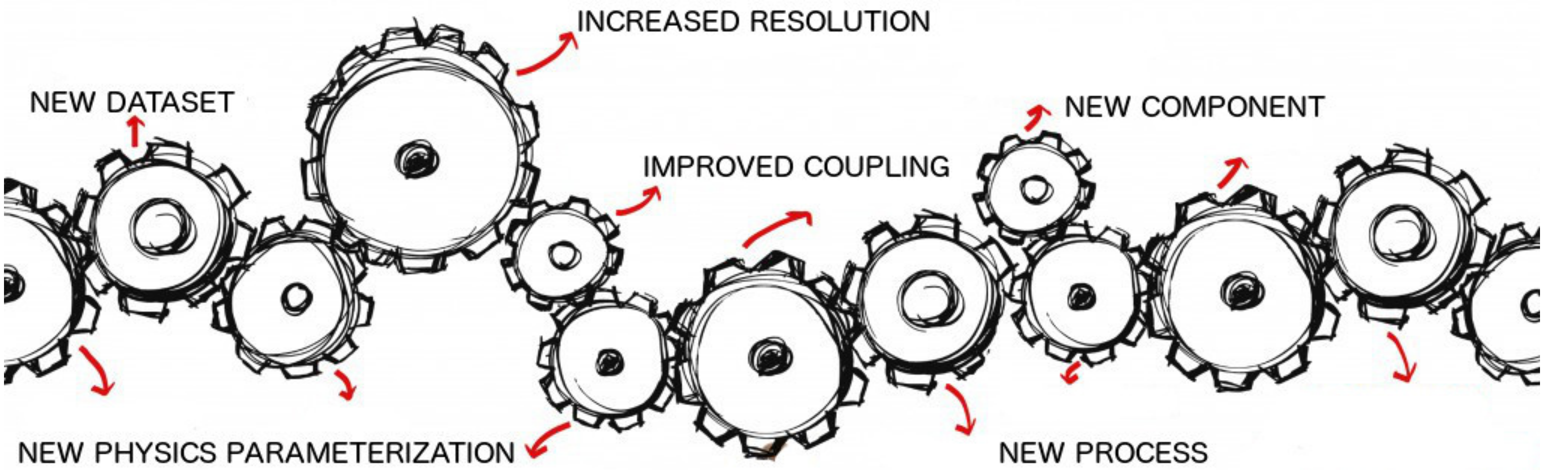


Coupling for ESM: The IGSM

MIT JOINT PROGRAM
SCIENCE POLICY
GLOBAL CHANGE

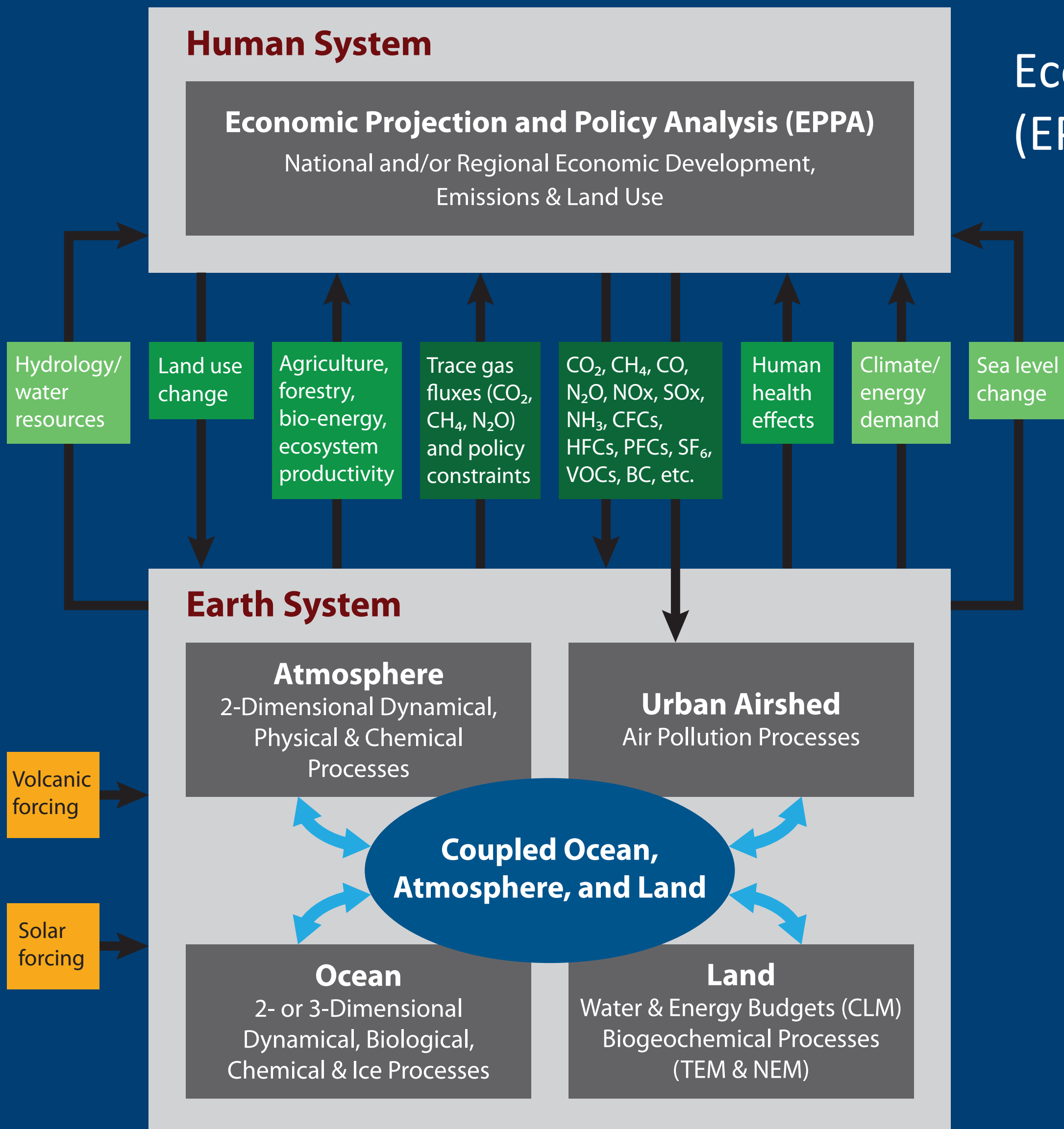
Erwan Monier

Massachusetts Institute of Technology

Snowmass 2016
Week 2

July 27, 2016

THE IGSM



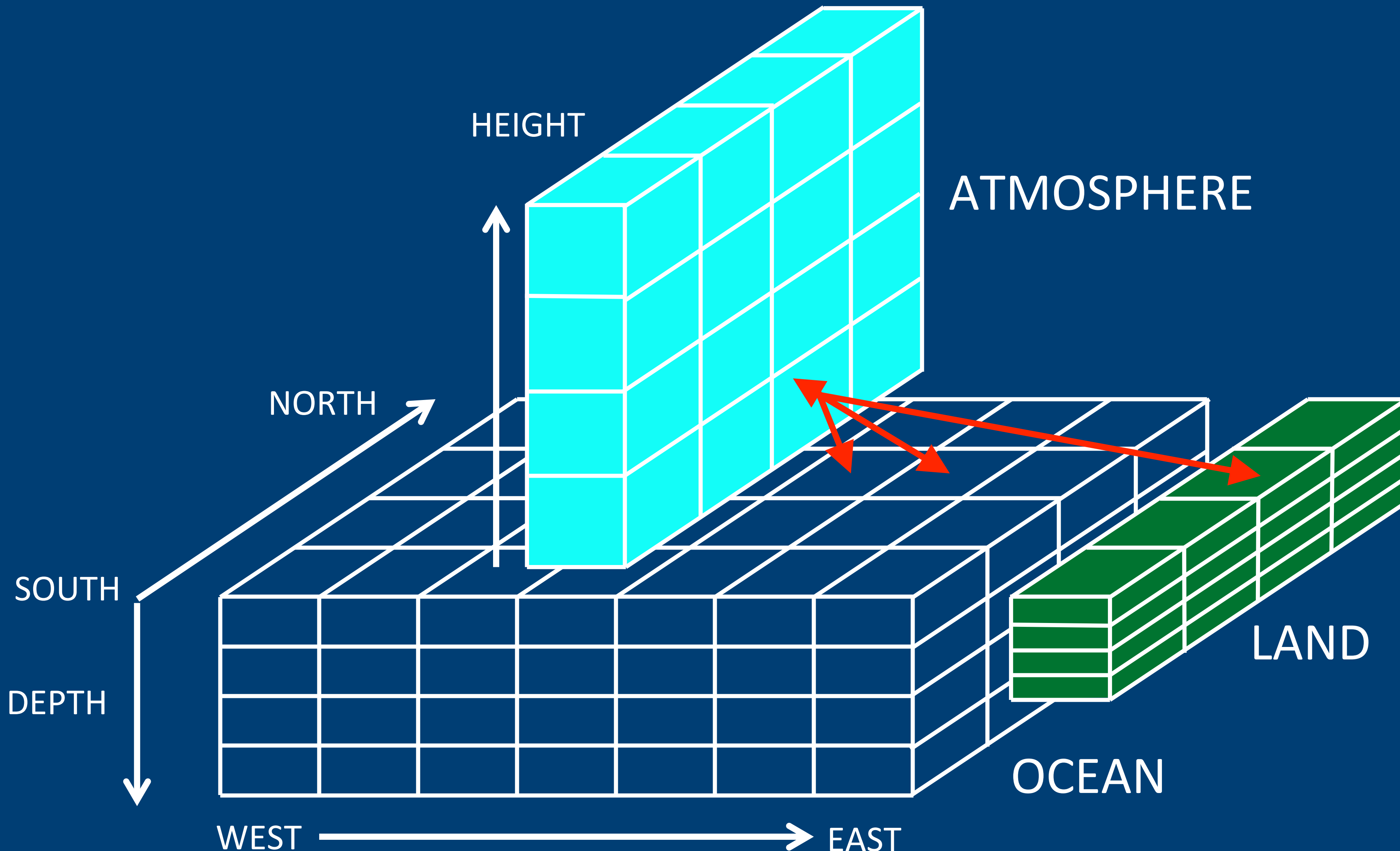
Economic Projection & Policy Analysis (EPPA):

- Global model
- Multi-region (18)
- Multi-sector
- Recursive dynamic computable general equilibrium (CGE) model

MIT Earth System Model (MESM):

- Earth System Model of Intermediate Complexity (EMIC)
- Land, atmosphere and ocean
- Full carbon cycle
- Atmospheric chemistry

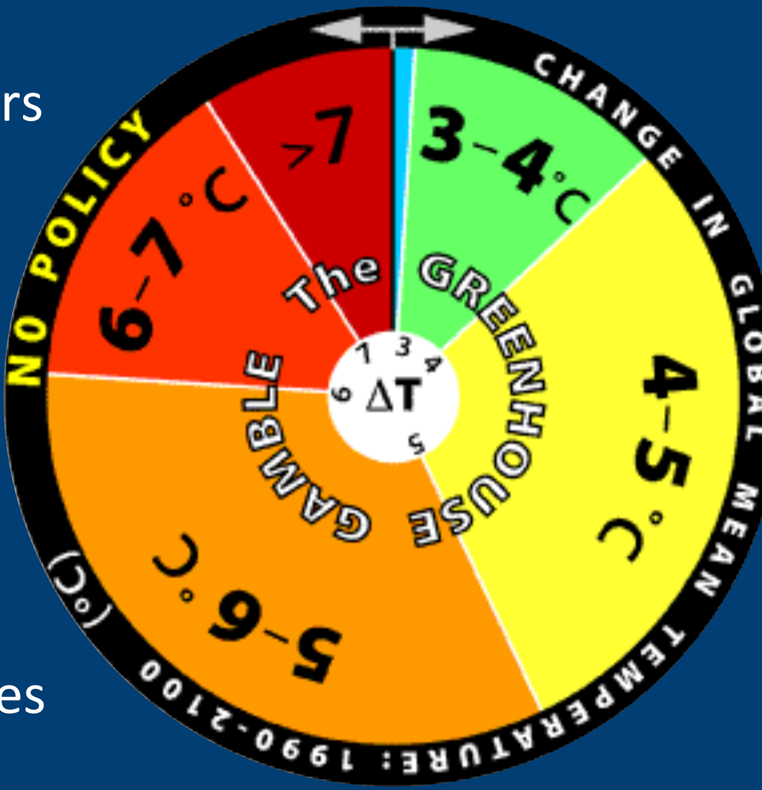
THE MESM



PROBABLISTIC PROJECTIONS

- Computational efficiency
  - A century-long run takes 12 hours on 1 cpu
  - Can easily run 1000s simulations

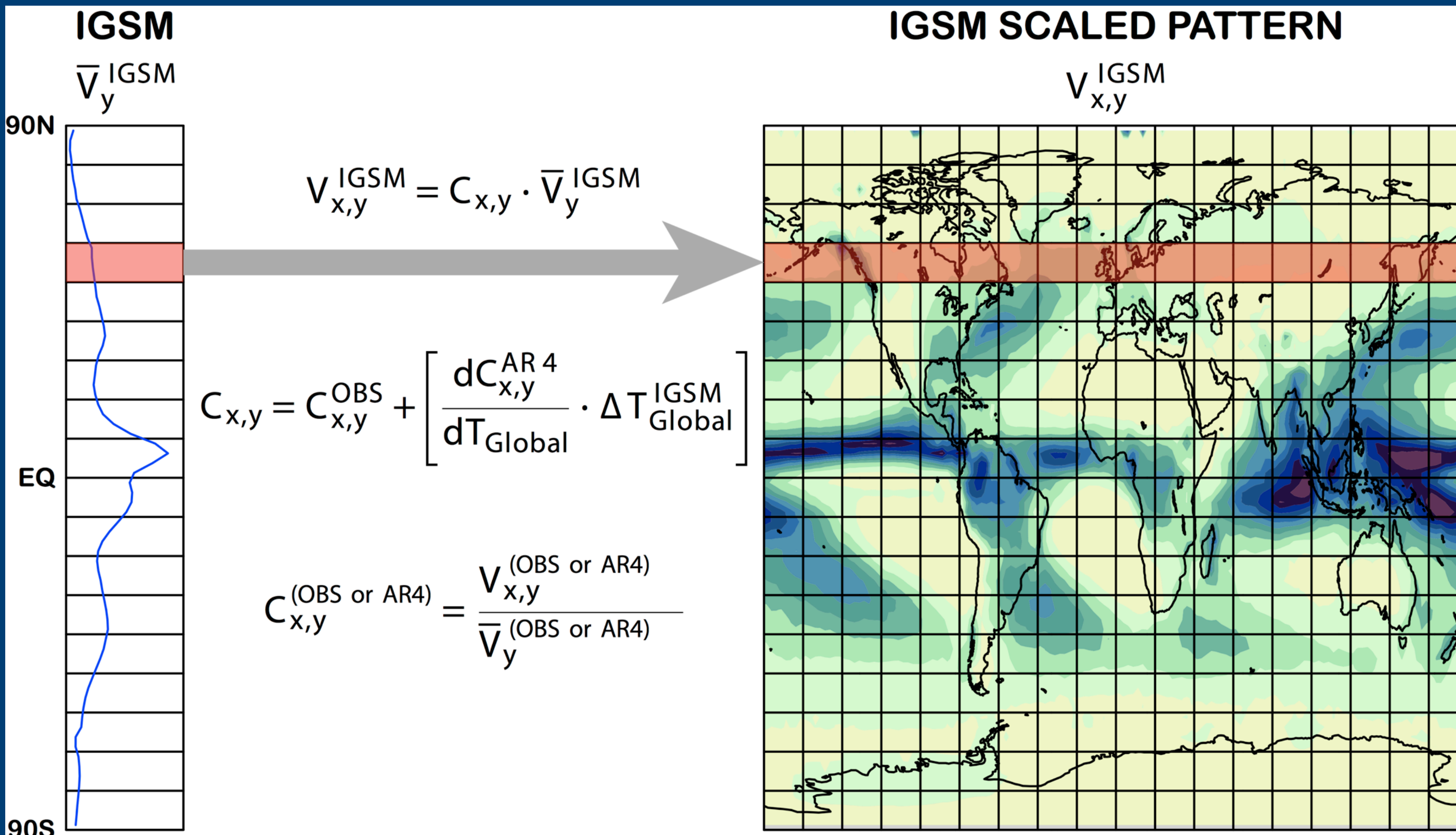
- Flexibility to change key climate parameters
  - climate sensitivity
  - strength of aerosol forcing
  - ocean heat uptake rate
  - strength of carbon cycle



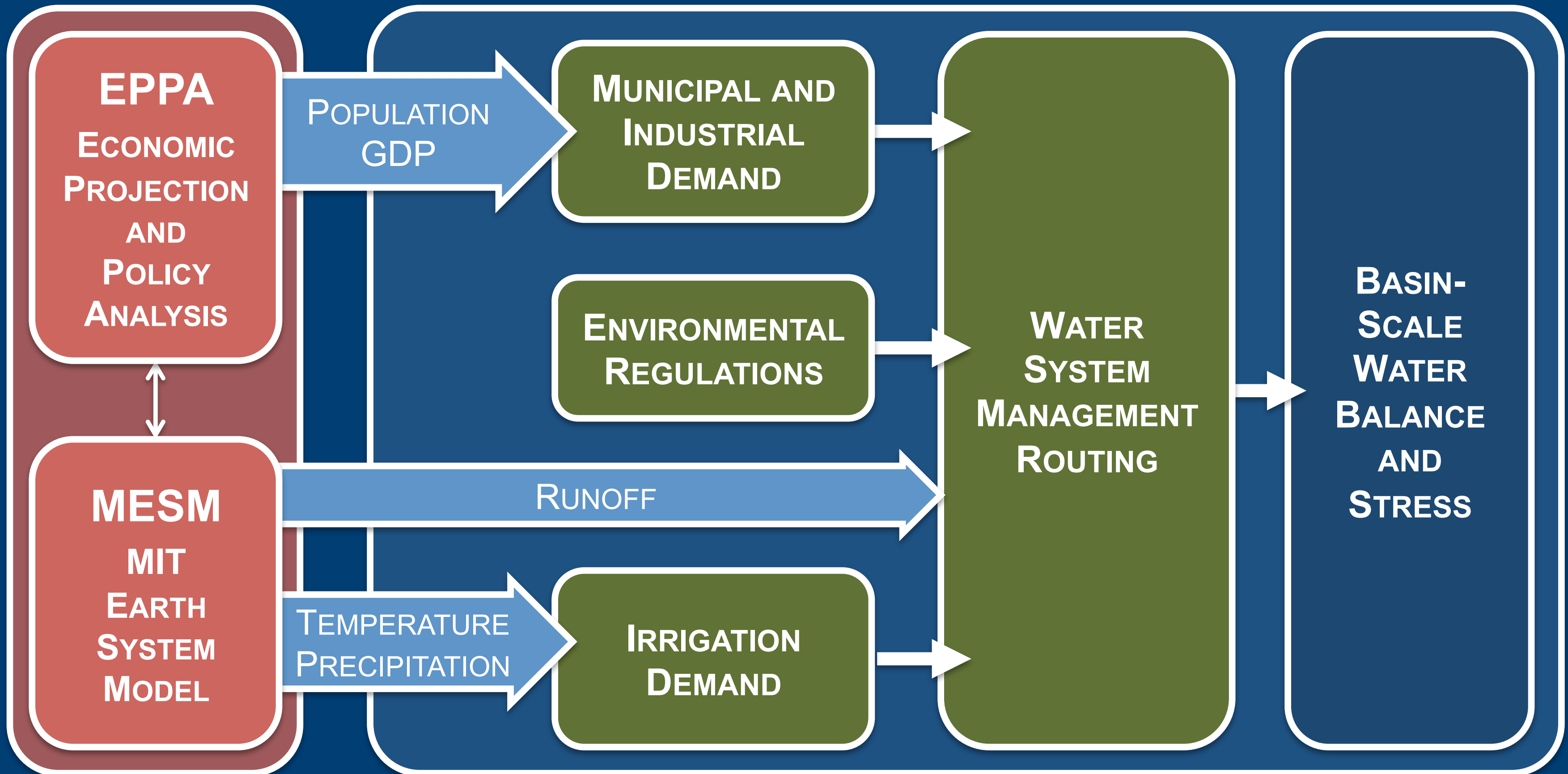
- PDFs of climate parameters
- Probabilistic projections of climate variables

STATISTICAL DOWNSCALING

Pattern scaling method:



WATER IMPACTS



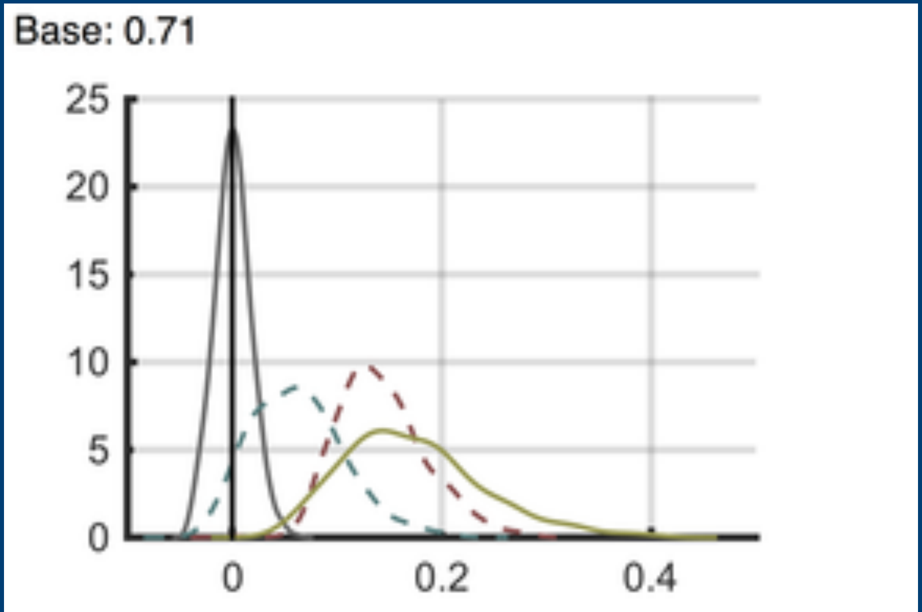
Monthly climate variables, biased corrected

Fant et al (2016) Projections of Water Stress Based on an Ensemble of Socioeconomic Growth and Climate Change Scenarios: A Case Study in Asia. PLoS ONE 11(3): e0150633.

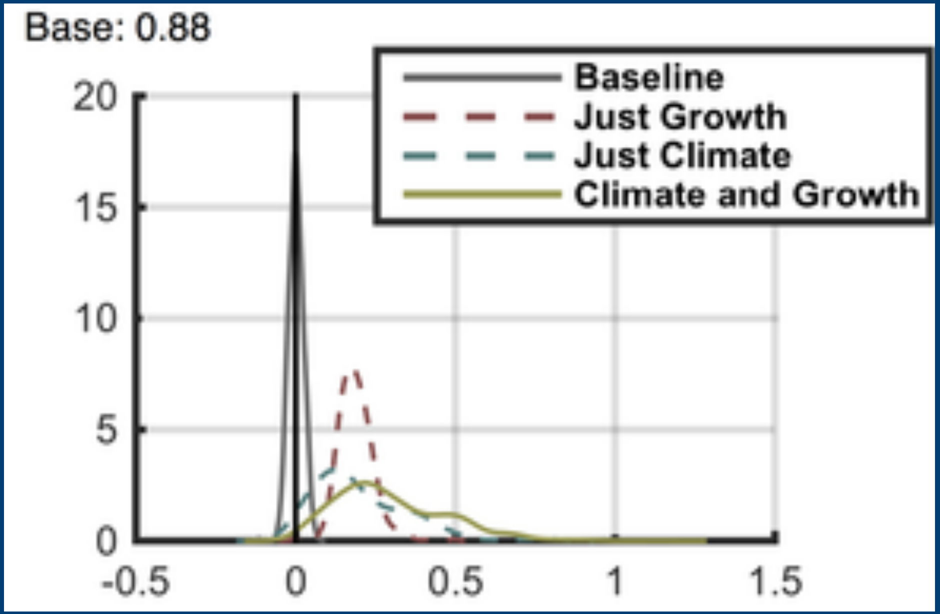
DISTRIBUTIONS OF WATER IMPACTS

CHANGE IN WATER STRESS INDEX (WSI) BY 2050

INDIA



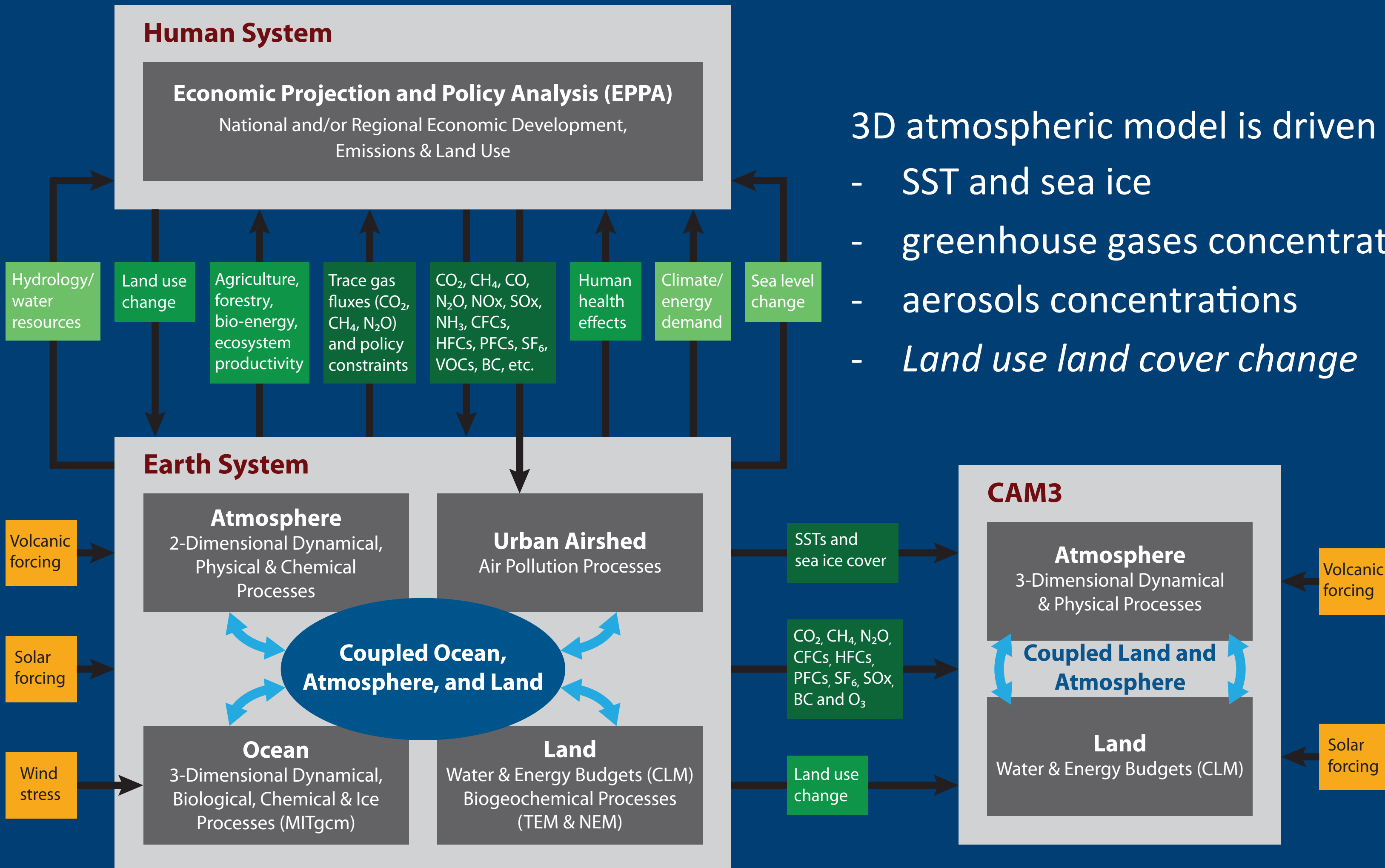
CHINA



Fant et al (2016) Projections of Water Stress Based on an Ensemble of Socioeconomic Growth and Climate Change Scenarios: A Case Study in Asia. PLoS ONE 11(3): e0150633.

DYNAMICAL DOWNSCALING

MIT IGSM-CAM framework:

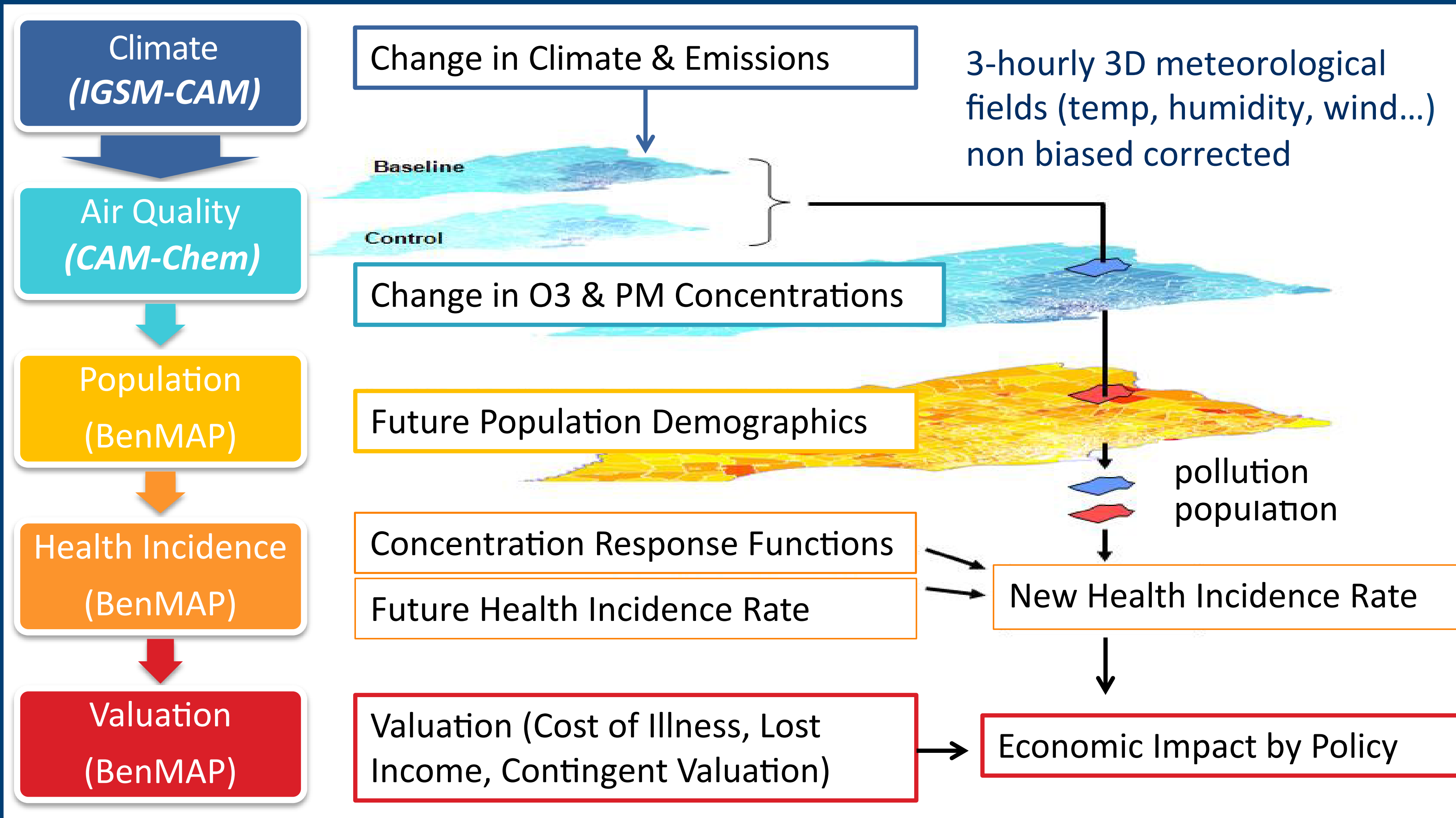


3D atmospheric model is driven by IGSM:

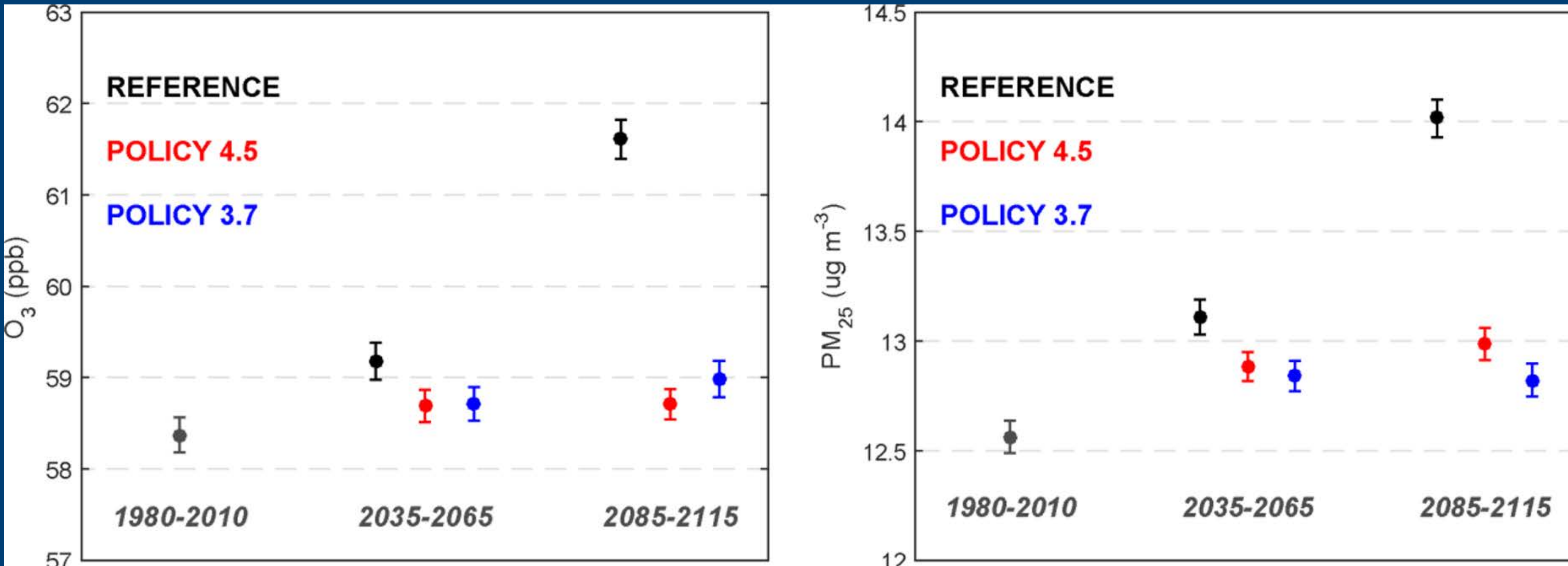
- SST and sea ice
- greenhouse gases concentrations
- aerosols concentrations
- *Land use land cover change*

AIR QUALITY AND HEALTH FRAMEWORK

Anthropogenic and biogenic emissions



AIR QUALITY AND HEALTH IMPACTS

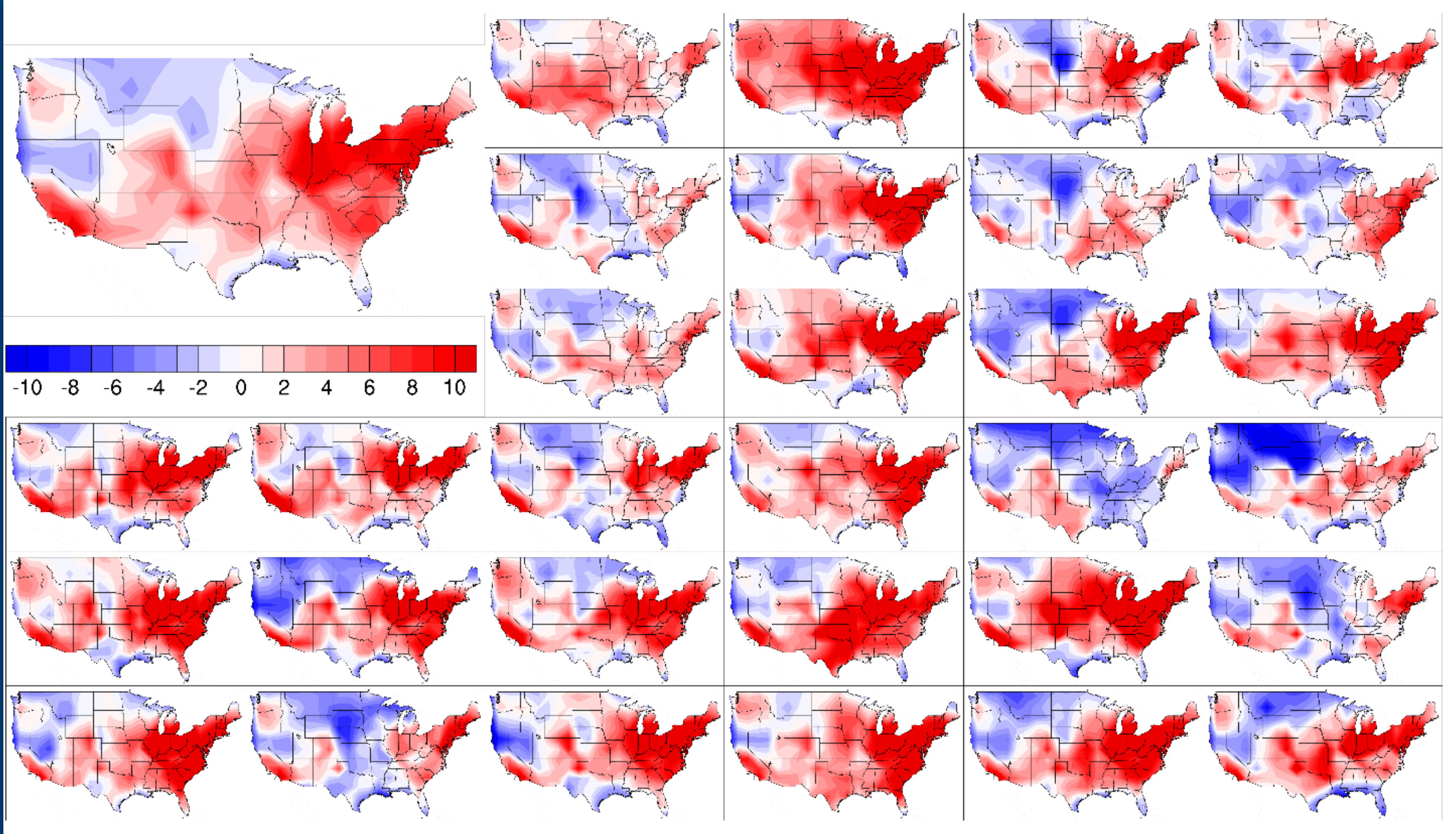


		Avoided deaths	life years saved (thousands)
REF -> POL4.5	2050	11,000 (4,000–19,000)	570 (210–940)
	2100	52,000 (19,000–87,000)	1,300 (240–2,500)
REF -> POL3.7	2050	13,000 (4,800- 22,000)	620 (230–1,000)
	2100	57,000 (21,000–95,000)	1,400 (240–2,600)

Garcia-Menendez et al (2015) US air quality and health benefits from avoided climate change under greenhouse gas mitigation. Environmental science & technology, 49(13), pp.7580-7588.

AIR QUALITY AND HEALTH IMPACTS

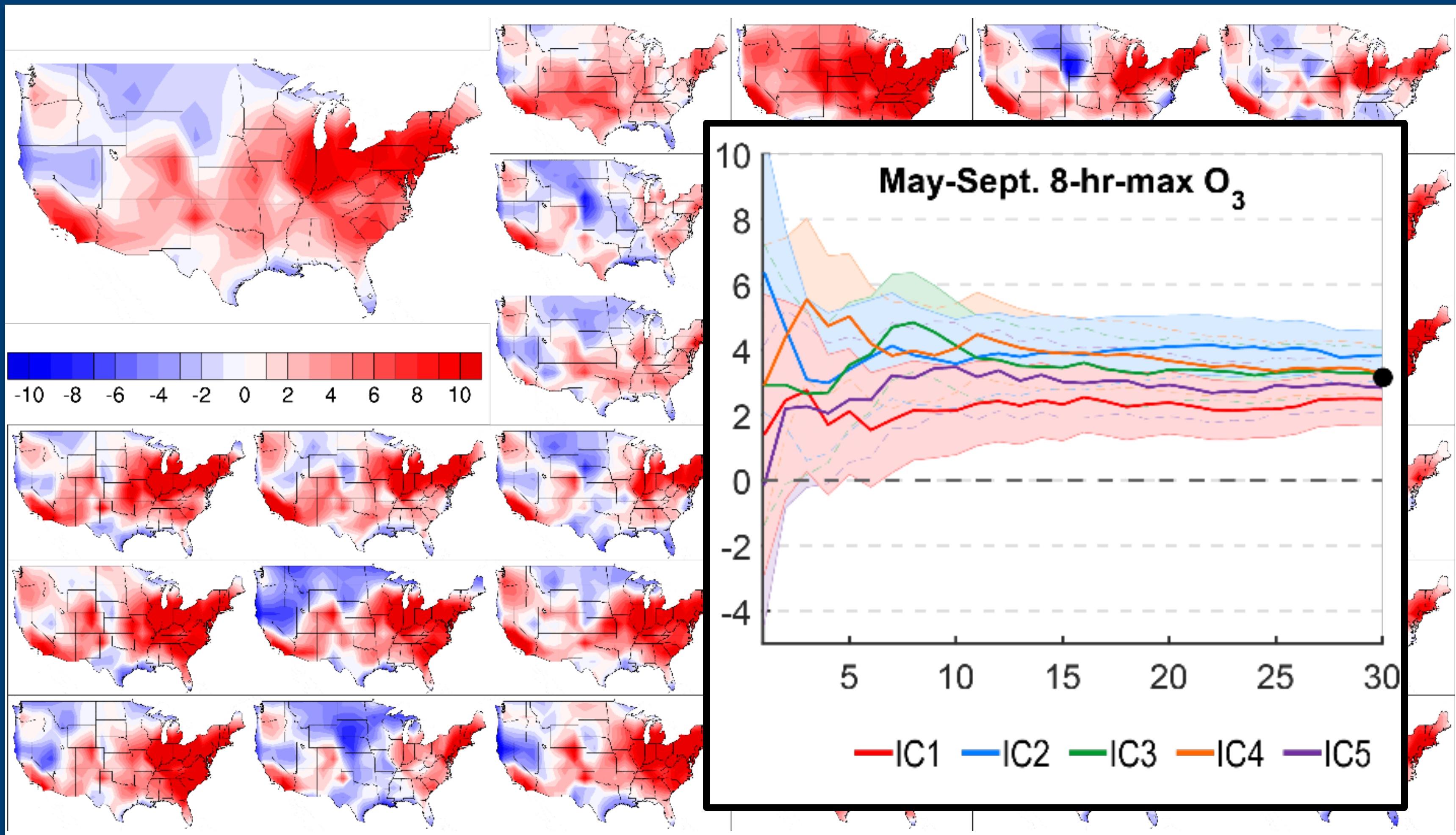
Changes in summer 8-h-max O_3 by 2100



Garcia-Menendez et al (2016) Natural variability in modeling assessments of climate change impacts on U.S. ozone pollution. Nature Climate Change, under review.

AIR QUALITY AND HEALTH IMPACTS

Changes in summer 8-h-max O_3 by 2100



Garcia-Menendez et al (2016) Natural variability in modeling assessments of climate change impacts on U.S. ozone pollution. Nature Climate Change, under review.

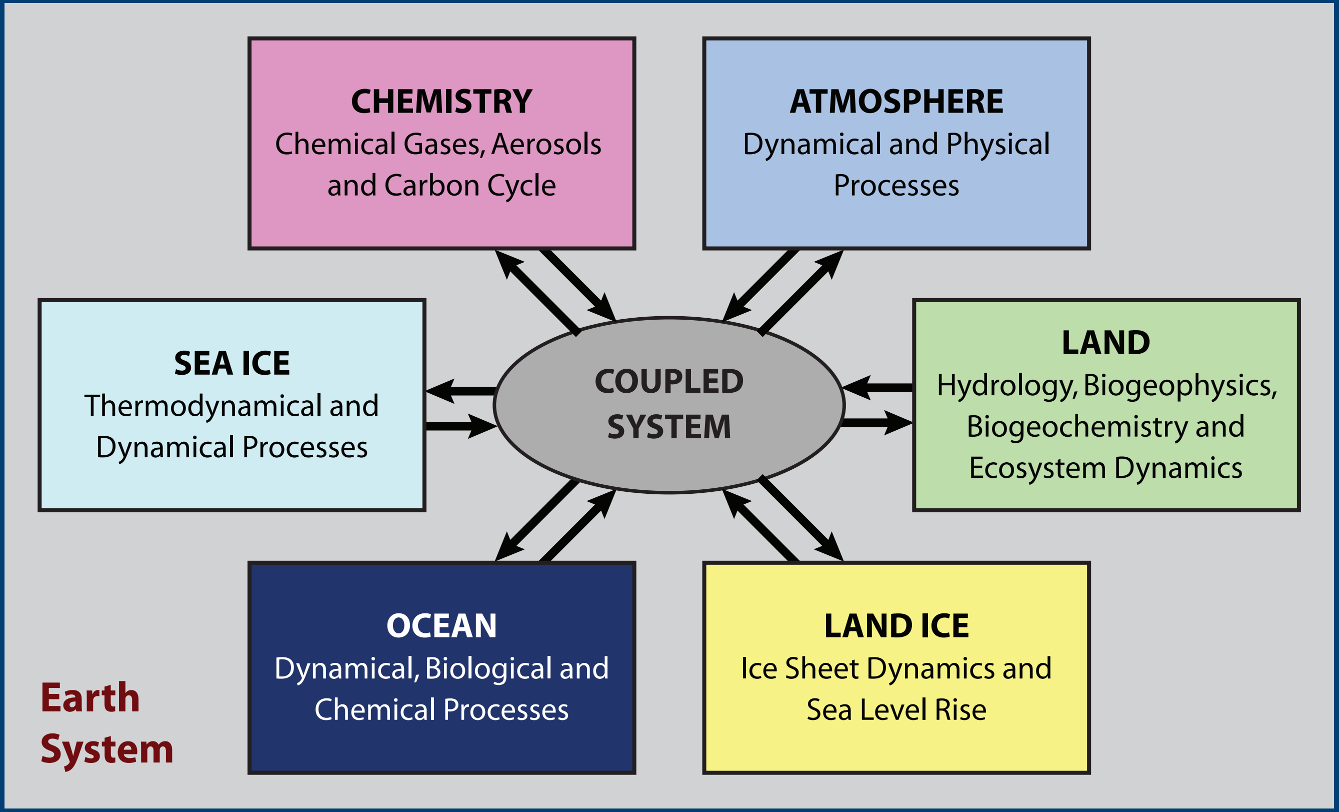
SUMMARY OF DOWNSCALING METHOD

Strengths and limitations of the 2 downscaling methods

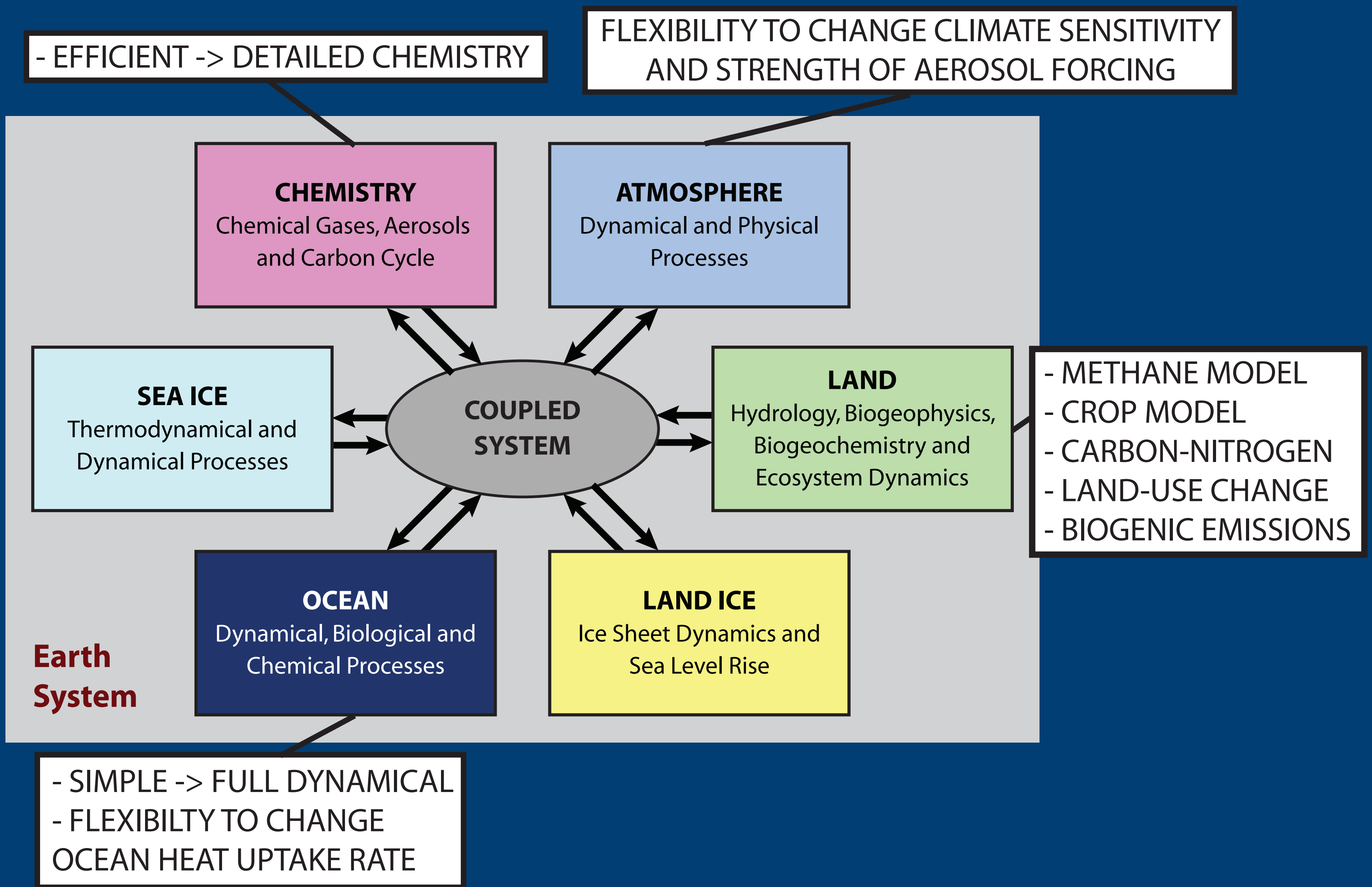
APPROACH	STRENGTHS	LIMITATIONS
IGSM-Pattern scaling (statistical approach)	• Can emulate multiple models • Computationally efficient • Can derive full distributions	• Limited to T and P • Limited to monthly time scale • Cannot simulate changes in variability and extremes
IGSM-CAM (dynamical approach)	• Can explore natural variability and extremes events • Not limited to T,P (can drive models requiring various input variables or 3D fields) • High temporal resolution	• Limited to a single model • Computationally intensive • Can only approximate the bounds of the distributions

Limited represented feedbacks (i.e. for regional climate change)

MESM 3D

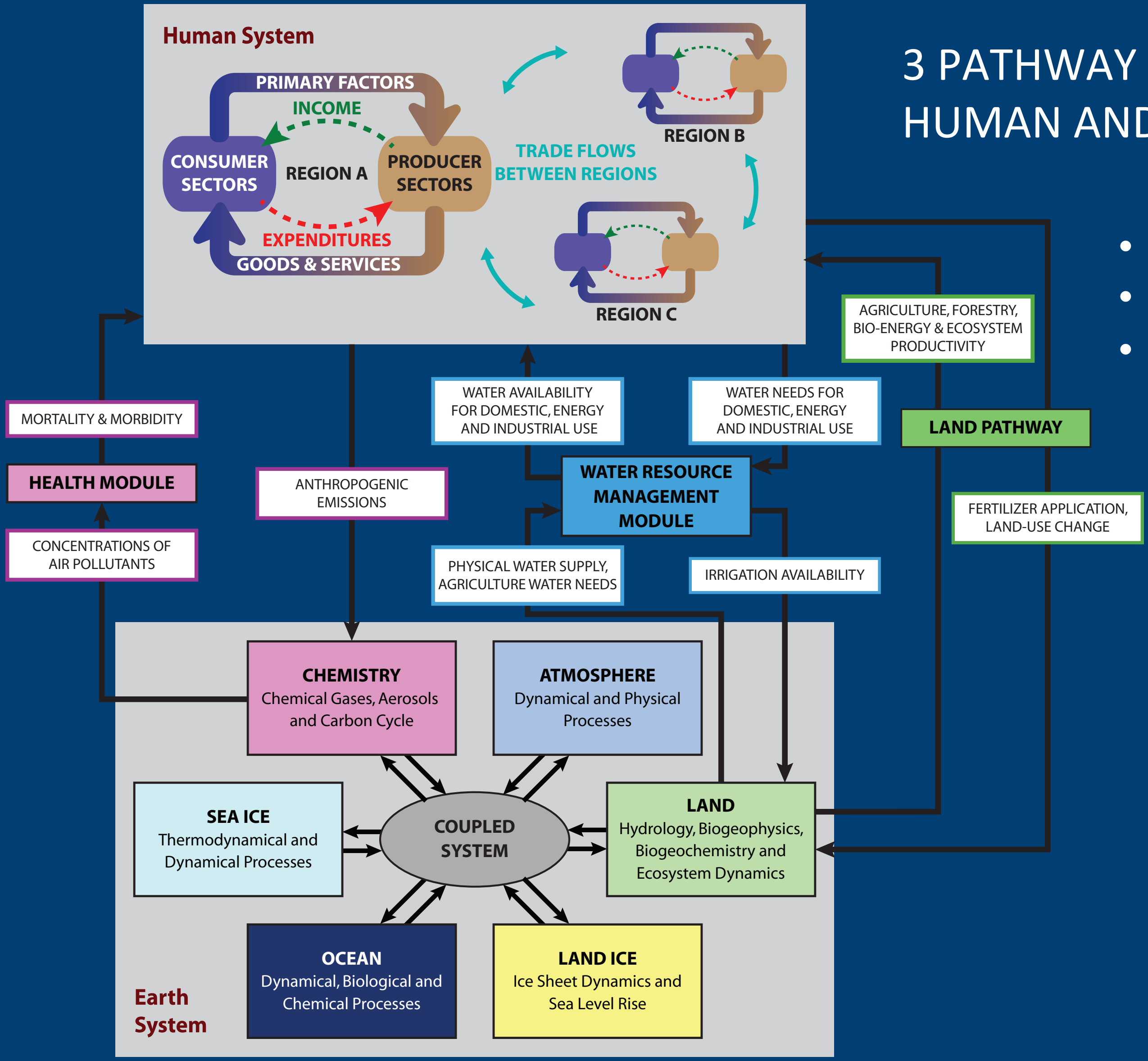

CHEMISTRY
Chemical Gases, Aerosols and Carbon Cycle
ATMOSPHERE
Dynamical and Physical Processes
SEA ICE
Thermodynamical and Dynamical Processes
COUPLED SYSTEM
LAND
Hydrology, Biogeophysics, Biogeochemistry and Ecosystem Dynamics
OCEAN
Dynamical, Biological and Chemical Processes
LAND ICE
Ice Sheet Dynamics and Sea Level Rise
Earth System

MESM 3D



- EFFICIENT -> DETAILED CHEMISTRY
FLEXIBILITY TO CHANGE CLIMATE SENSITIVITY AND STRENGTH OF AEROSOL FORCING
CHEMISTRY
Chemical Gases, Aerosols and Carbon Cycle
ATMOSPHERE
Dynamical and Physical Processes
SEA ICE
Thermodynamical and Dynamical Processes
COUPLED SYSTEM
LAND
Hydrology, Biogeophysics, Biogeochemistry and Ecosystem Dynamics
- METHANE MODEL
- CROP MODEL
- CARBON-NITROGEN
- LAND-USE CHANGE
- BIOGENIC EMISSIONS
OCEAN
Dynamical, Biological and Chemical Processes
LAND ICE
Ice Sheet Dynamics and Sea Level Rise
Earth System
- SIMPLE -> FULL DYNAMICAL
- FLEXIBILTY TO CHANGE OCEAN HEAT UPTAKE RATE

IGSM 3D

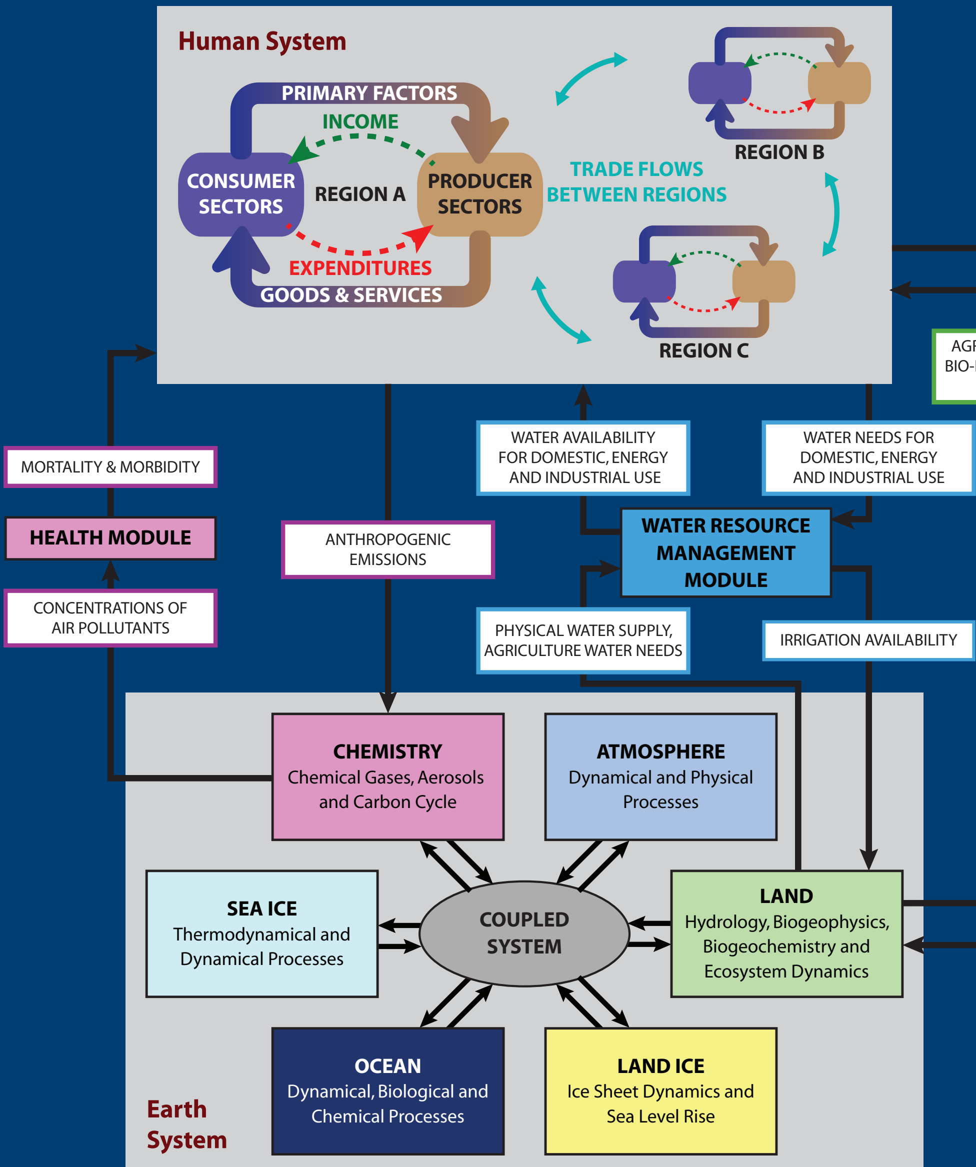


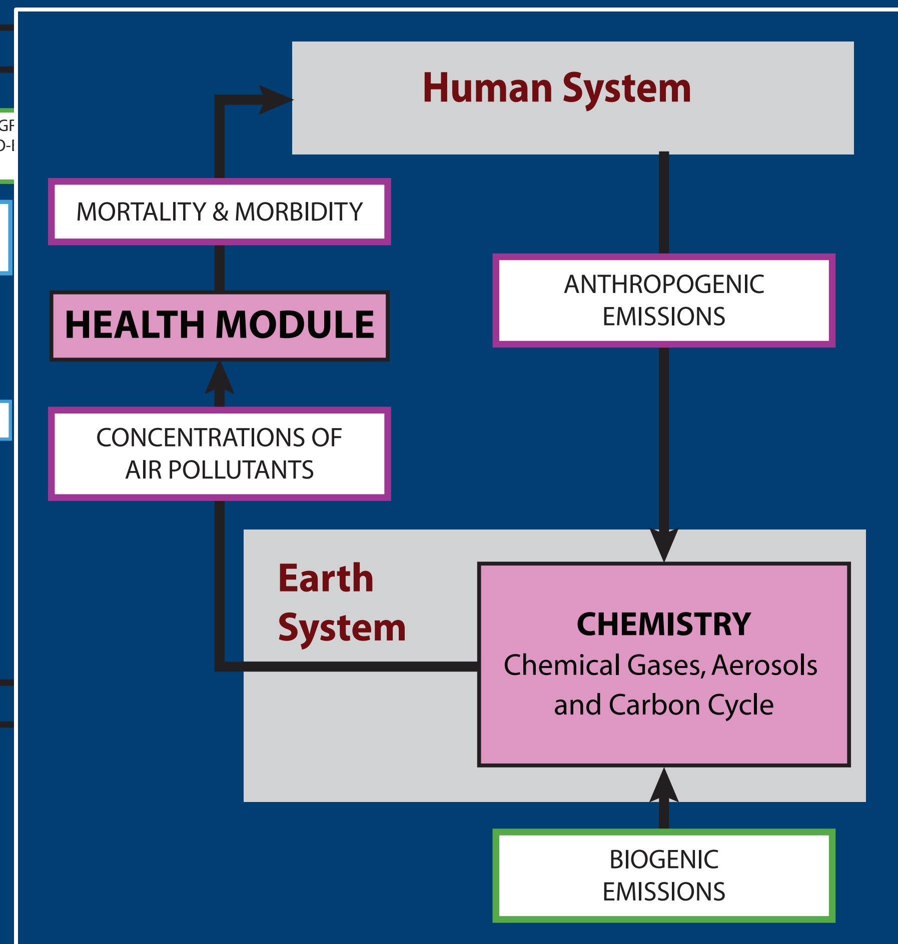
3 PATHWAY FOR COUPLING BETWEEN HUMAN AND EARTH SYSTEMS:

- AIR QUALITY & HEALTH
- WATER RESOURCES
- LAND

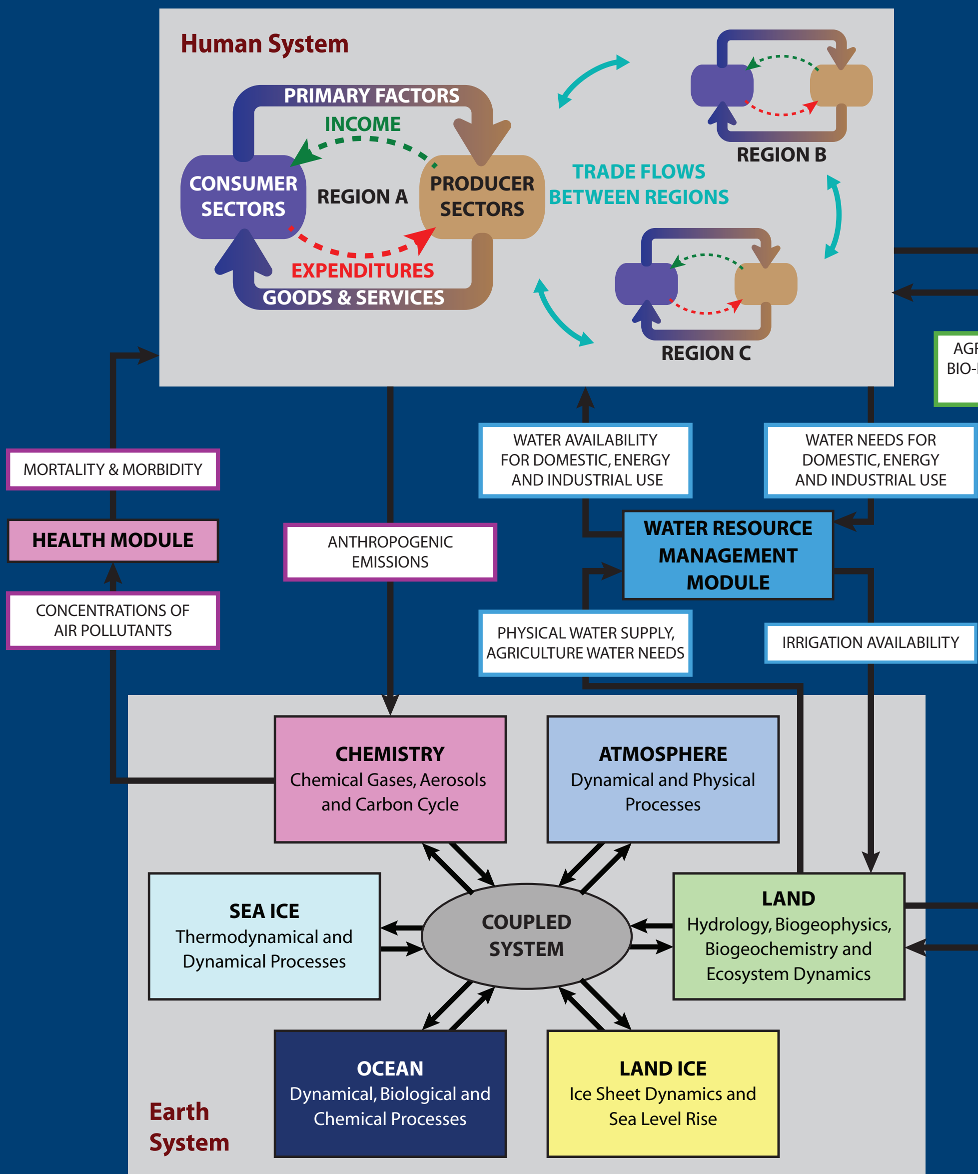
IGSM 3D

3 PATHWAY FOR COUPLING BETWEEN HUMAN AND EARTH SYSTEMS:





IGSM 3D



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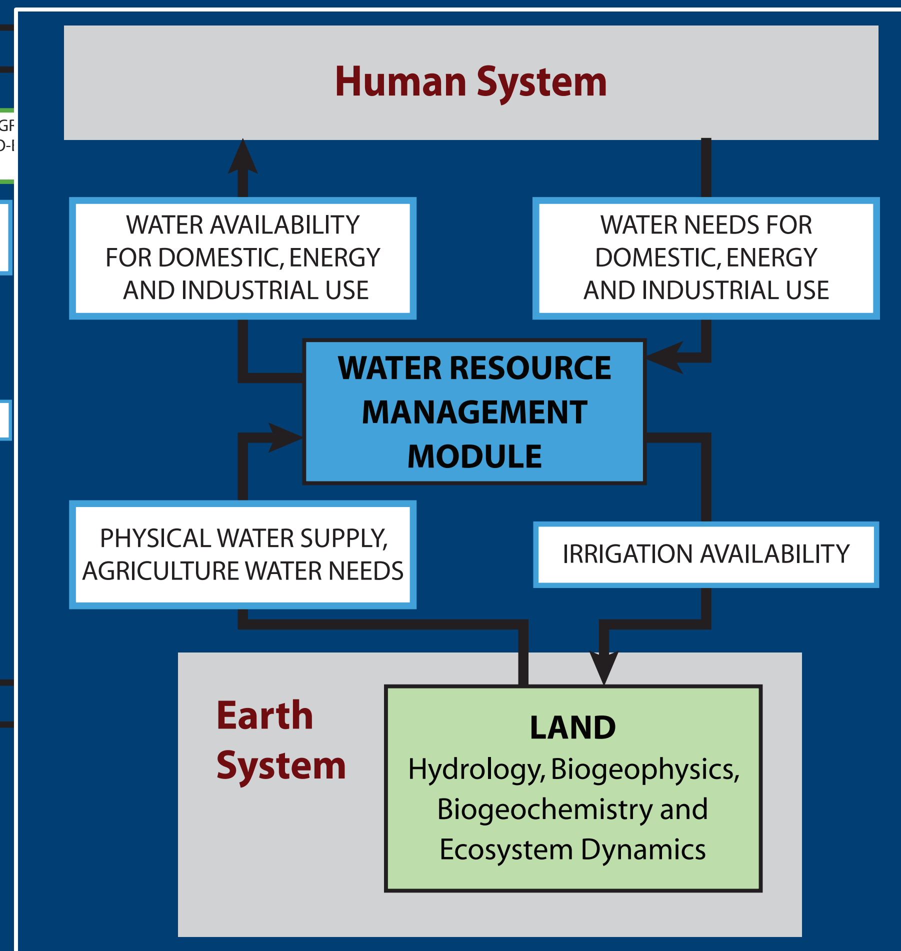
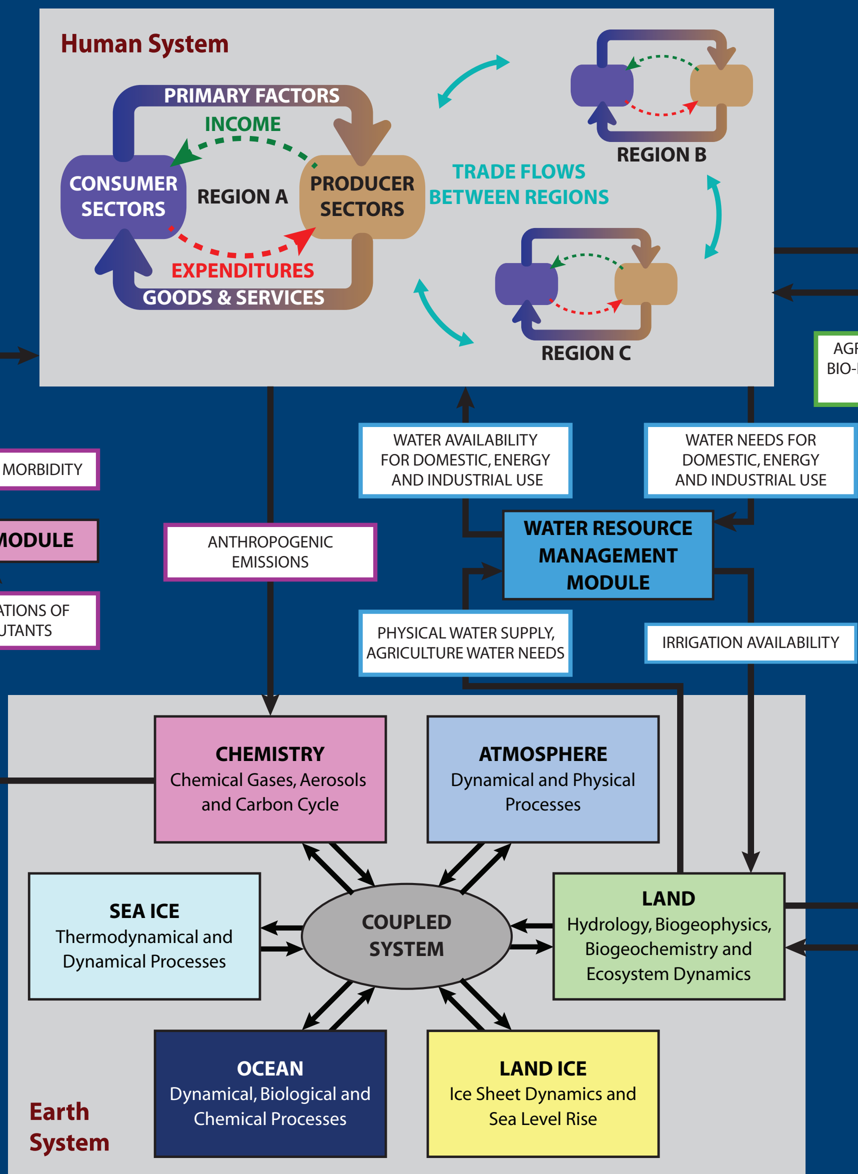


IGSM 3D



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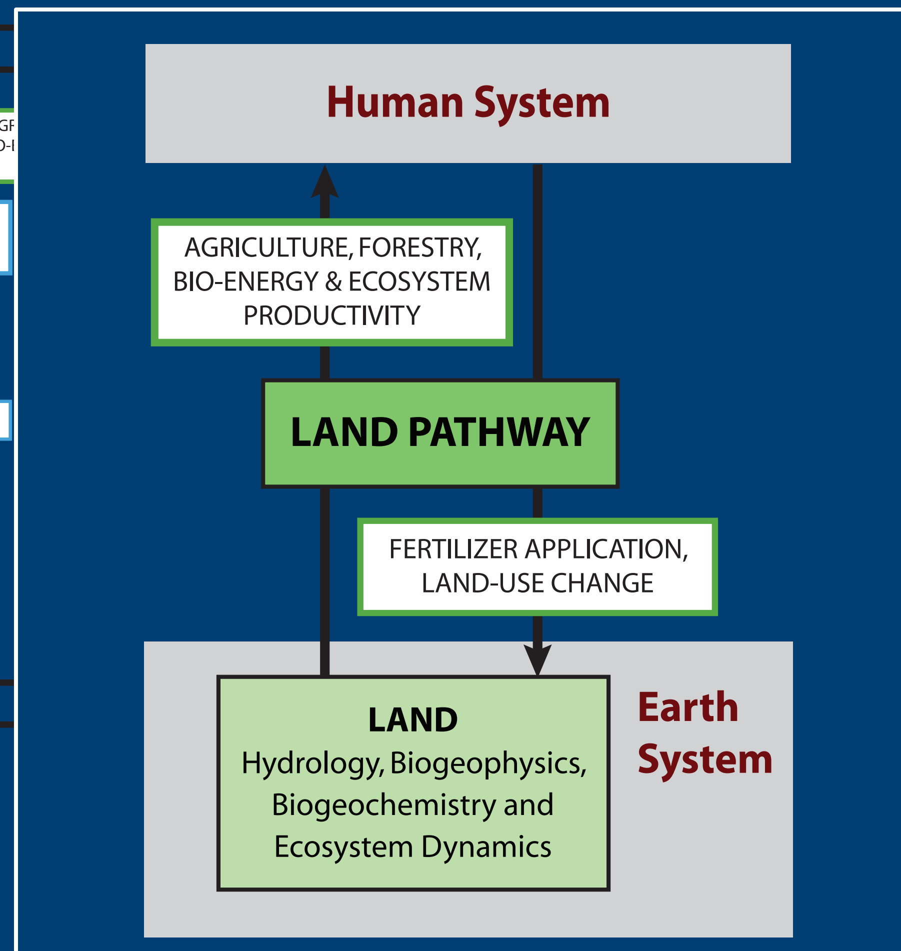

GOAL OF NEW IGSM VERSION

- Build a more complete hierarchy of IGSM frameworks
- Toward a more integrated representation of the human-earth system
  - more realistic(?)
- Are feedbacks between human and earth systems important?
  - Land-use change <-> regional climate change
- Are interactions between multi-sector impacts/co-benefits important?
  - Air quality & land-use change (biogenic emissions, ozone damage)
  - Water scarcity & crop production (irrigation)
- Better explore the role of natural variability on climate impacts

ALWAYS THE SAME ISSUES

- Spatial resolution/complexity of model vs. uncertainty analysis
  Is it too complex?
- Bias correction vs. representation of feedbacks
- Temporal resolution / coupling strategies
- Consistency in data / management practices within the framework
- Many more I couldn't think about when I prepared the presentation…

THANK YOU

ANY QUESTIONS?