Overview of Integrated Assessment Models

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Improving the Assessment and Valuation of Climate Change Impacts for Policy and Regulatory Analysis

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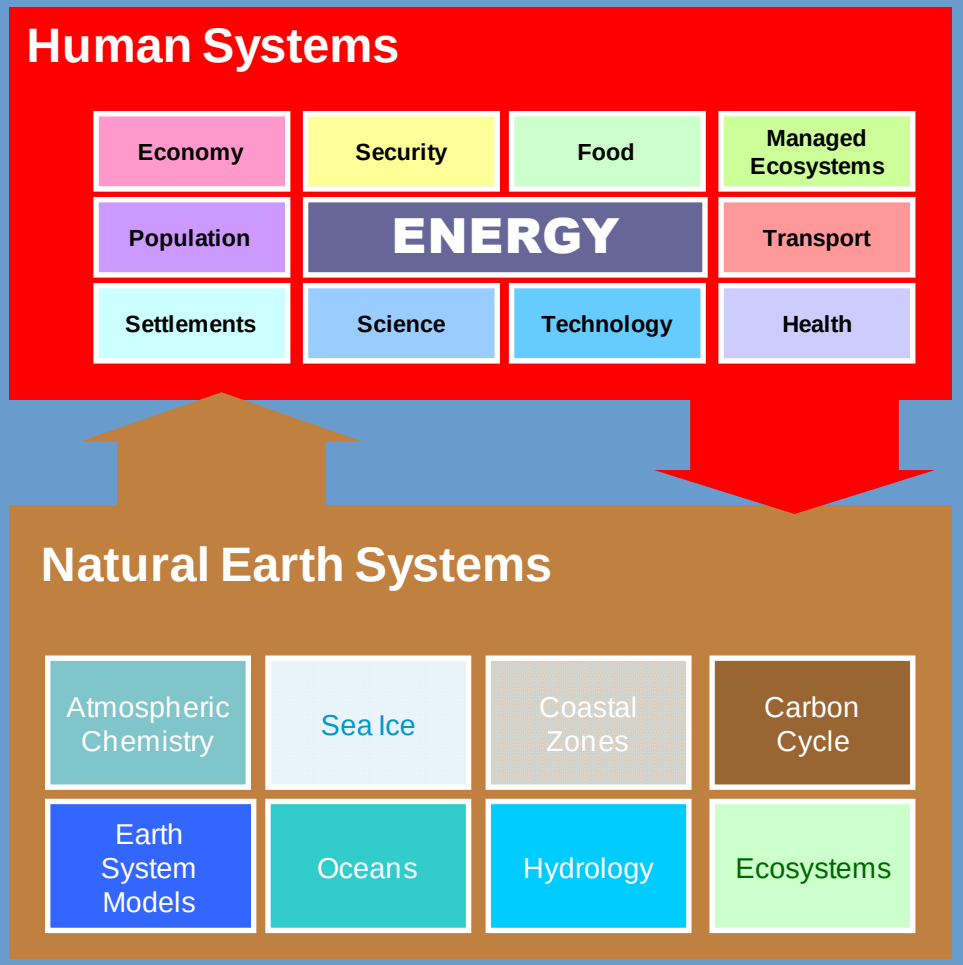
What is an Integrated Assessment Model (IAM)?

IAMs integrate human and natural Earth system climate science.

- IAMs provide insights that would be otherwise unavailable from disciplinary research.
- IAMs capture interactions between complex and highly nonlinear systems.
- IAMs provide natural science researchers with information about human systems such as GHG emissions, land use and land cover.

IAMs provide important, science-based decision support tools.

- IAMs support national, international, regional, and private-sector decisions.



IAMs Are Strategic in Nature

- IAMs were designed to provide strategic insights.
- IAMs were never designed to model the very fine details, e.g.
  - Electrical grid operation
  - Daily oil market price paths.
- IAMs are analogous to climate models in that sense.
  - Climate models don't forecast weather
  - They were designed to describe the determinants of 30-year moving averages of weather.
- IAMs also span a wide range of models with highly varied levels of spatial and temporal resolution.

Example of an IA insight: Sulfur & Land use

- Carbon tax cases can have higher radiative forcing than non-control scenarios.
  - Sulfur
  - Land-use change emissions

- I don’t have the original figure because it predates the age of PowerPoint.

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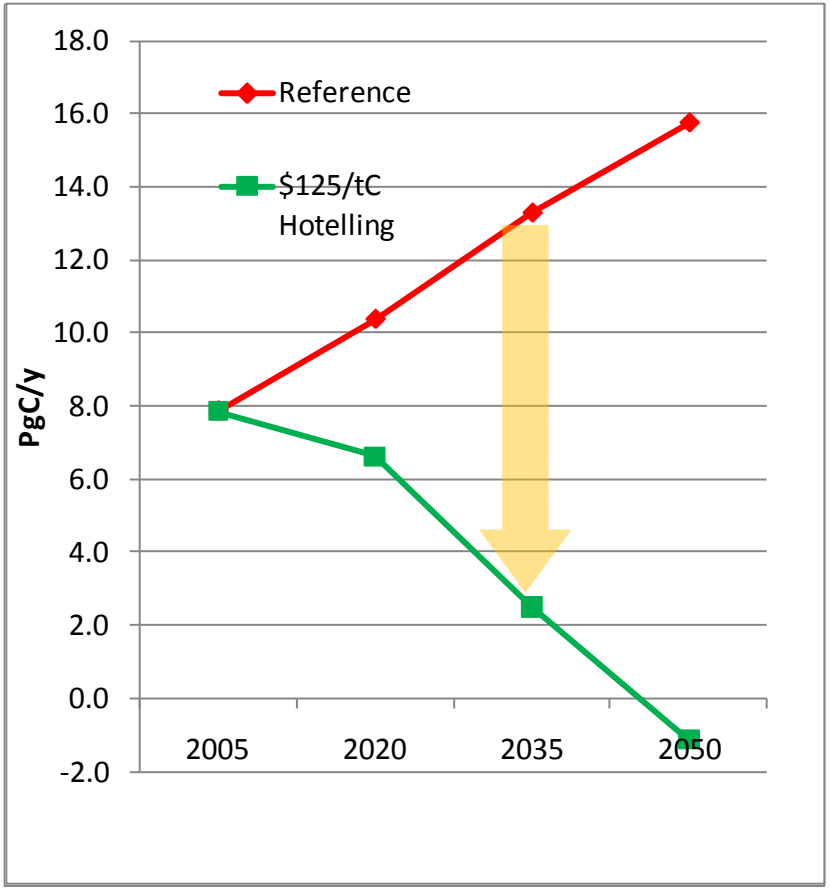
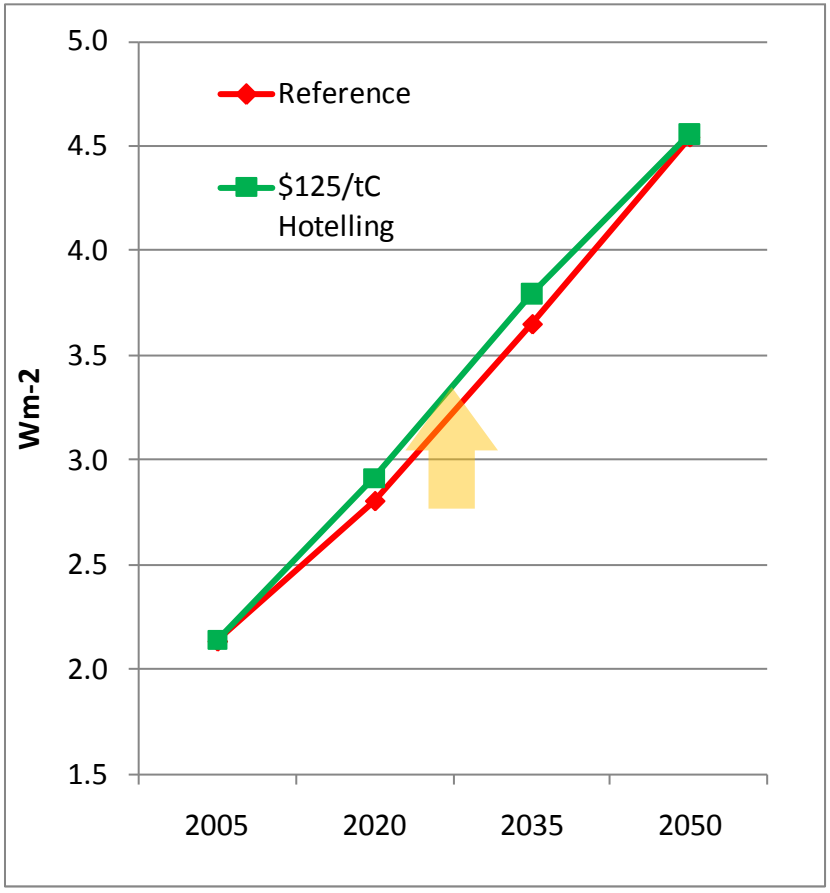
Example of an IA insight: Sulfur & Land use

- **Consider a reference scenario, e.g. reference to GCAM RCP 4.5, and a scenario in which fossil fuel and industrial carbon is taxed.**

Fossil Fuel & Industrial Carbon Emissions



Total Anthropogenic Radiative Forcing



- Radiative Forcing goes up prior to 2050 because of the sulfur aerosol and indirect land-use effects.

“HORSES FOR COURSES”
–JAKE JACOBY

IAMs are a diverse set of tools

- The diversity of IAMs is a reflection of the diversity of problems for which the models were designed to address.
  - What is the optimal climate policy?
  - Implications of policy regimes for technology choice?
  - How do policy, energy, the economy, land use and terrestrial carbon cycle interact?
- IAMs are evolving to address new questions
  - How will emissions mitigation and climate impacts interact?
- The bigger the question, the more aggregated the model.

THE HIGHLY AGGREGATED IA MODELS

Three BIG question models: DICE, FUND & PAGE

- As far as I can remember, this line of investigation begins with a series of discussion papers written by Bill Nordhaus in 1989 and 1990 leading to the DICE model.

- These models are characterized by high levels of **aggregation** and **comprehensiveness**.
  - Typically come in 3 parts.
    - Emissions
    - Natural Earth systems (atmospheric composition & climate change)
    - Climate Damages
  - RICE (the regional version of DICE) is ~17 equations
  - For comparison, GCAM is ~110,000 lines of code

Sources of Information

- Highly aggregated IAMs face the problem of establishing parameter values for the three major components—emissions, natural Earth systems, and climate damages.

- Most highly aggregated IAMs summarize information gleaned from other, more detailed models or from off-line research.
  - The relationship between the more highly resolved IAMs and the highly aggregated IAMs is similar in nature to the relationship between the Earth system models of intermediate complexity (EMICs) and the high resolution Earth system models (ESMs).
  - But the highly aggregated IAMs also derive information from other research domains, most notably the Impacts, adaptation and vulnerability (IAV) community.
  - (Climate research can be divided into IAV, IAM, and atmosphere-climate modeling domains.)

The highly aggregated IAMs are often used for the purpose of comparing the costs and benefits of policy intervention. This introduces several additional issues.

1. How to compare non-market damages?
   - Value of a human life—just ask David Pearce.
   - Value of unmanaged ecosystems.
   - While these problems are amenable to economic analysis, actual values are vigorously debated.
2. How to include interaction effects?
   - Across sectors—agriculture, energy and water
   - Mitigation and adaptation—who gets the land?
   - Land-use change from mitigation and adaptation affect climate?
3. How to compare across time—and not just one week or year to the next, but across multiple generations.

3. For the US, how to compare across space—should damages in distant lands be weighted as heavily as damages at home?

4. The tails of the distribution
   - Climate change potentially pushes the Earth system into regimes that have not been observed for millions of years.
     - And, even then big things are different, e.g. the placement of the continents.
   - Extreme and catastrophic events are possible.
     - Both events that might be imagined—e.g. rapid destabilization of clathrate zones, and.
     - Events that have not yet been imagined—the rapid emergence of the ozone hole was the consequence of heterogeneous chemistry that was not in the models until after the hole needed to be explained.
     - What is the proper weight to give to such events?

THE HIGHER RESOLUTION IA MODELS

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The Higher Resolution IA Models Address Different Problems

- Higher resolution IAMs address questions associated with the details of the interactions between human and natural Earth systems.
  - The high resolution IAM economies are more disaggregated;
  - The high resolution IAM energy system technologies are highly varied;
  - Land use and land cover strongly interact with the economy, energy systems, and natural terrestrial processes.

- The higher resolution IAMs tend to focus on outputs in their natural units.
  - How many new nuclear builds?
  - How many Pg of CO_2 in geologic repositories?
  - What impact will climate change have on the price of wheat?

Cost effectiveness

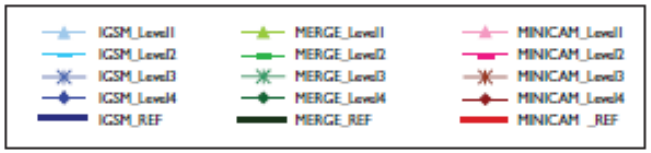
- The higher resolution IA models have focused on cost-effectiveness
  - What is the best way to stabilize CO_2 concentrations?
  - What is the best way to limit global mean surface temperature (GMST) not to exceed 2 degrees?

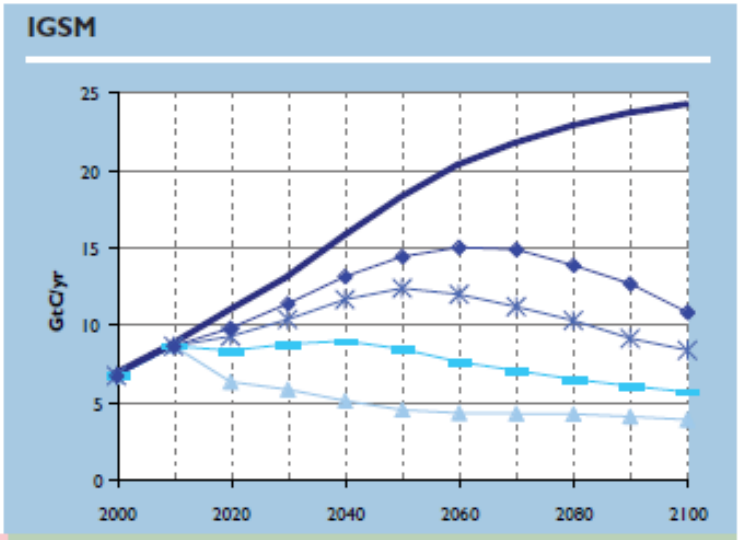
- Rich Richels' classic slide

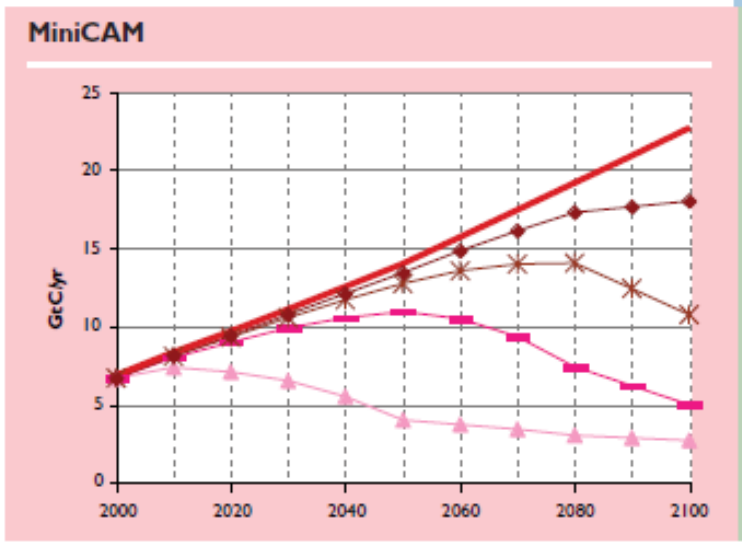
This is a cost-effectiveness study, NOT a cost-benefit study!!!

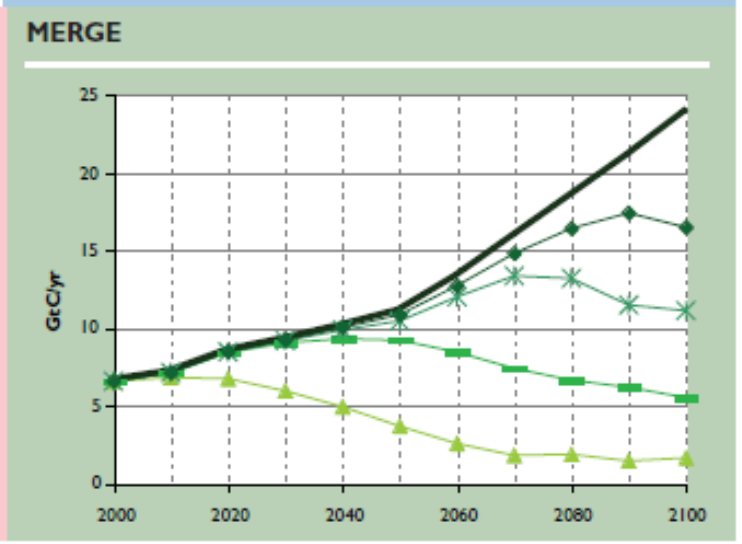
Cost effectiveness—SAP 2.1a

Figure TS.10 Global Emissions of CO_2 from Fossil and other Industrial Sources Across Scenarios (GtC/yr).
The tighter the constraint on radiative forcing, the faster carbon emissions must decline from those in the reference scenarios. This is because the stabilization level defines a long-term carbon budget; that is, the remaining amount of carbon that can be emitted in the future. The gradual deflection of the emissions from the reference reflects the assumption of *when* flexibility, with carbon prices rising gradually. Under the most stringent radiative forcing stabilization levels, CO_2 emissions begin to decline immediately or within a matter of decades. Under less stringent radiative forcing stabilization levels, CO_2 emissions do not peak until late in the century or beyond, and they are 1½ to over 2½ times today's levels in 2100.









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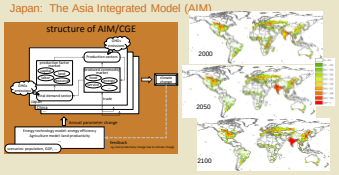
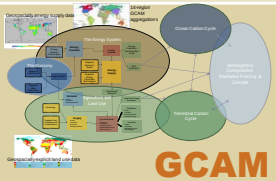
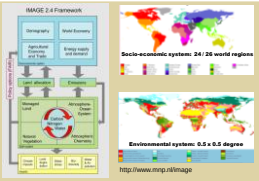
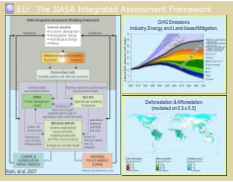
Cost effectiveness

- Because the higher resolution IA models have focused on cost-effectiveness, they haven't had to worry that much about the problems of impacts, and impact valuation. For example,
  - They haven't worried about the tails of the distribution—they simply take the goal of limiting GMST to 2 degrees.
  - Policy-technology interactions have loomed large.
  - Discounting has been a lesser issue.
  - Enumerating a complete set of atmosphere-climate impacts has not been critical.
- That situation is changing as the higher resolution IA models focus more on impacts.

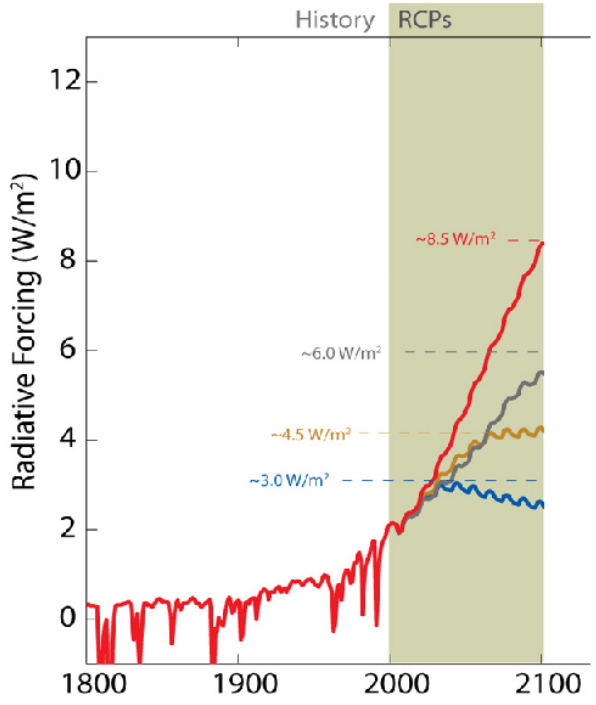
- The higher resolution of these models mean that interactions between sectors, regions, mitigation, adaptation, and climate can begin to be studied.

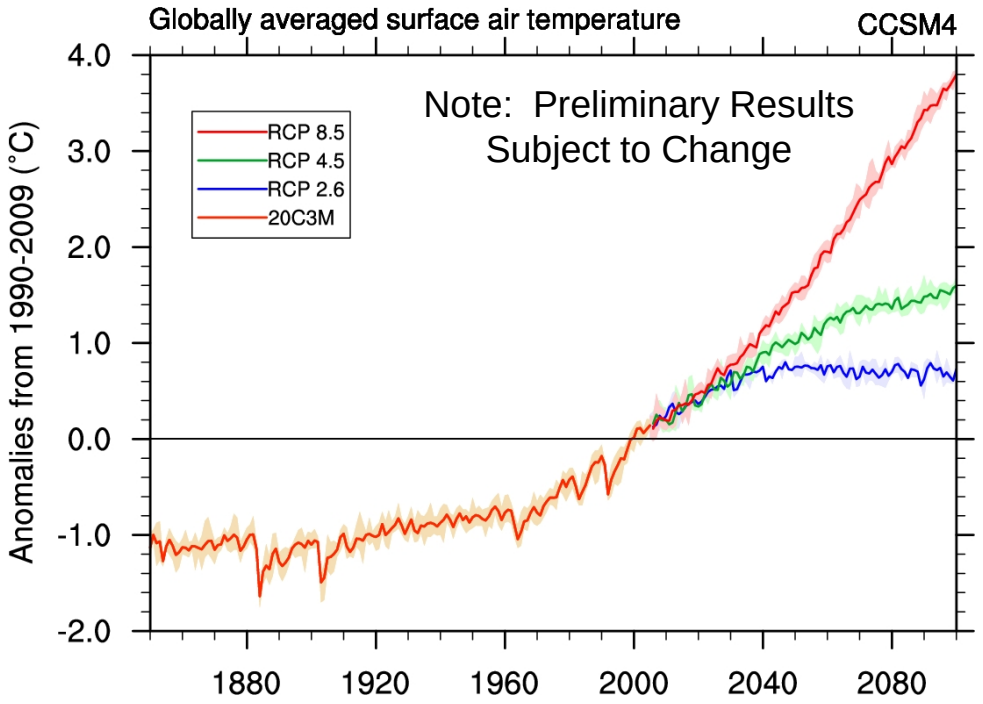
Higher Resolution Integrated Assessment Models are developed by interdisciplinary teams.

Model	Home Institution	
AIM Asia Integrated Model	National Institutes for Environmental Studies, Tsukuba Japan	
GCAM Global Change Assessment Model	Joint Global Change Research Institute, PNNL, College Park, MD	
IGSM Integrated Global System Model	Joint Program, MIT, Cambridge, MA	
IMAGE The Integrated Model to Assess the Global Environment	PBL Netherlands Environmental Assessment Agency, Bildhoven, The Netherlands	
MERGE Model for Evaluating the Regional and Global Effects of GHG Reduction Policies	Electric Power Research Institute, Palo Alto, CA	
MESSAGE Model for Energy Supply Strategy Alternatives and their General Environmental Impact	International Institute for Applied Systems Analysis; Laxenburg, Austria	

Higher resolution IAMs have provided atmosphere & climate models with both emissions and LULC trajectories

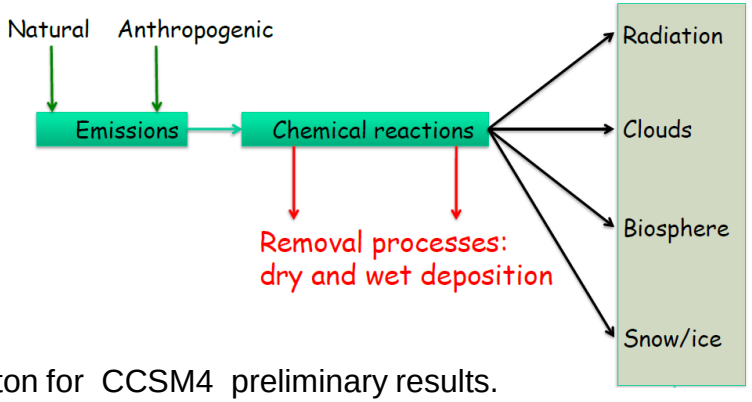
Emissions → Atmosphere → Climate





GHG Emissions and Concentrations from IAMs

- Greenhouse gases: CO_2, CH_4, N_2O, CFCs, HFC's, PFC's, SF_6
- Emissions of chemically active gases: CO, NO_x, NH_3, VOCs
- Derived GHG's: tropospheric O_3
- Emissions of aerosols: SO_2, Black Carbon (BC), Organic Carbon (OC)
- Land use and land cover

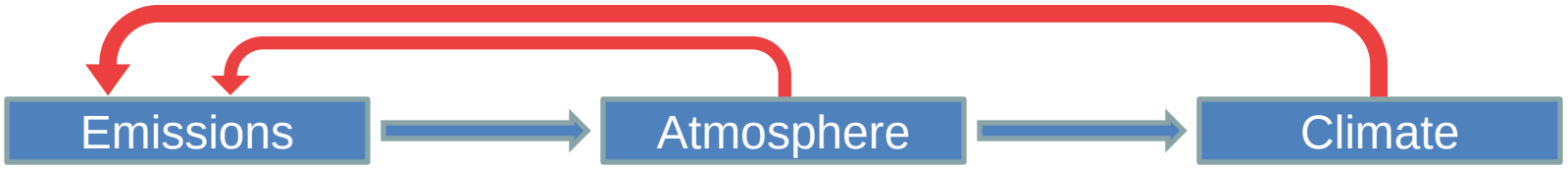


Thanks to Warren Washington for CCSM4 preliminary results.

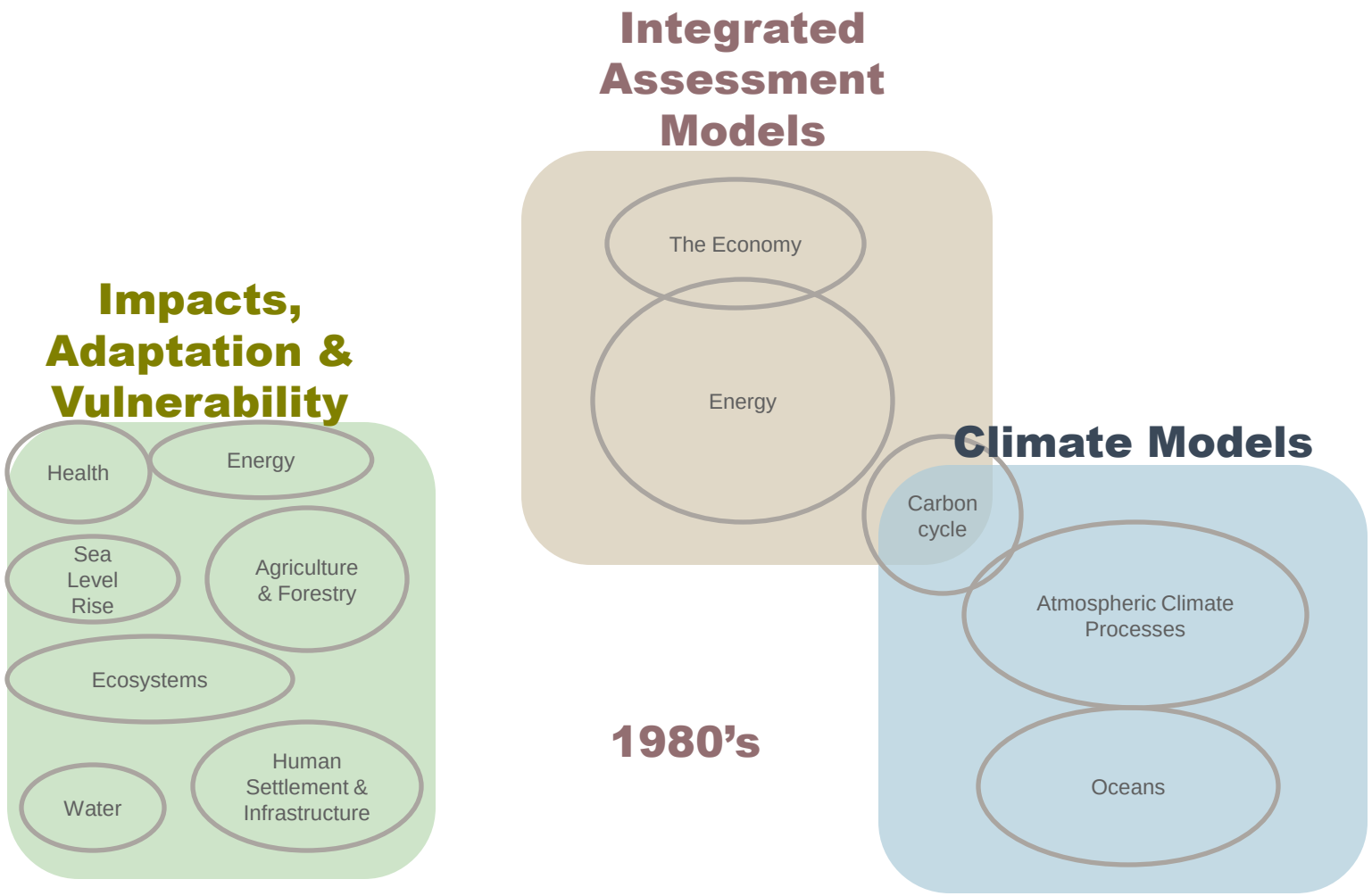
The iESM

- ***Models that integrate state of the art human Earth system models (taken from IAMs) with natural Earth system models (ESMs) are being actively developed.***

- ***The iESMs will provide feedbacks from atmosphere, oceans, and climate on terrestrial systems.*** E.g. climate and atmospheric composition feedbacks on crop yields, energy demands, bioenergy prices and climate mitigation.



Growing Overlap in Research Domains



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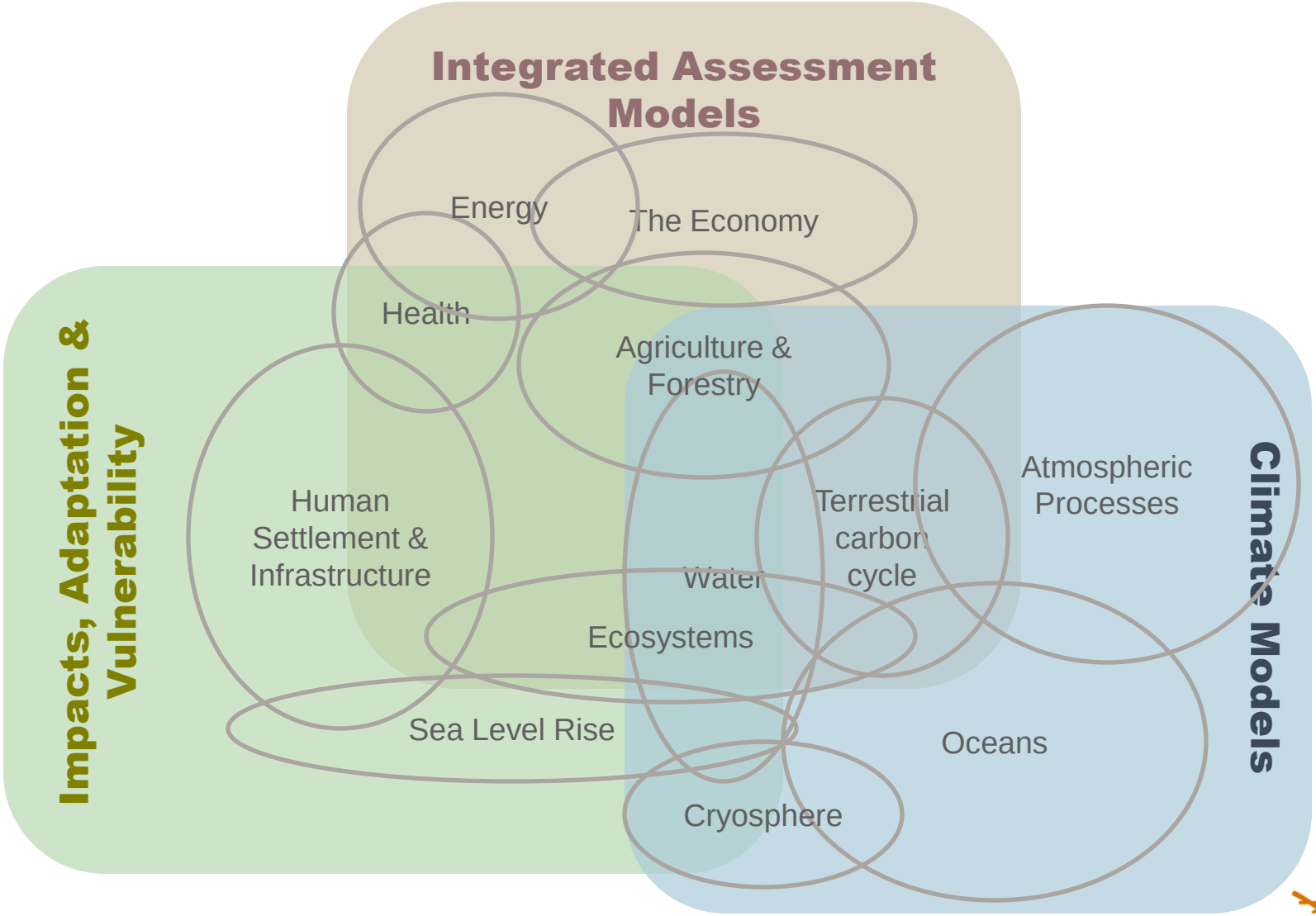
Where IAMs Are Headed



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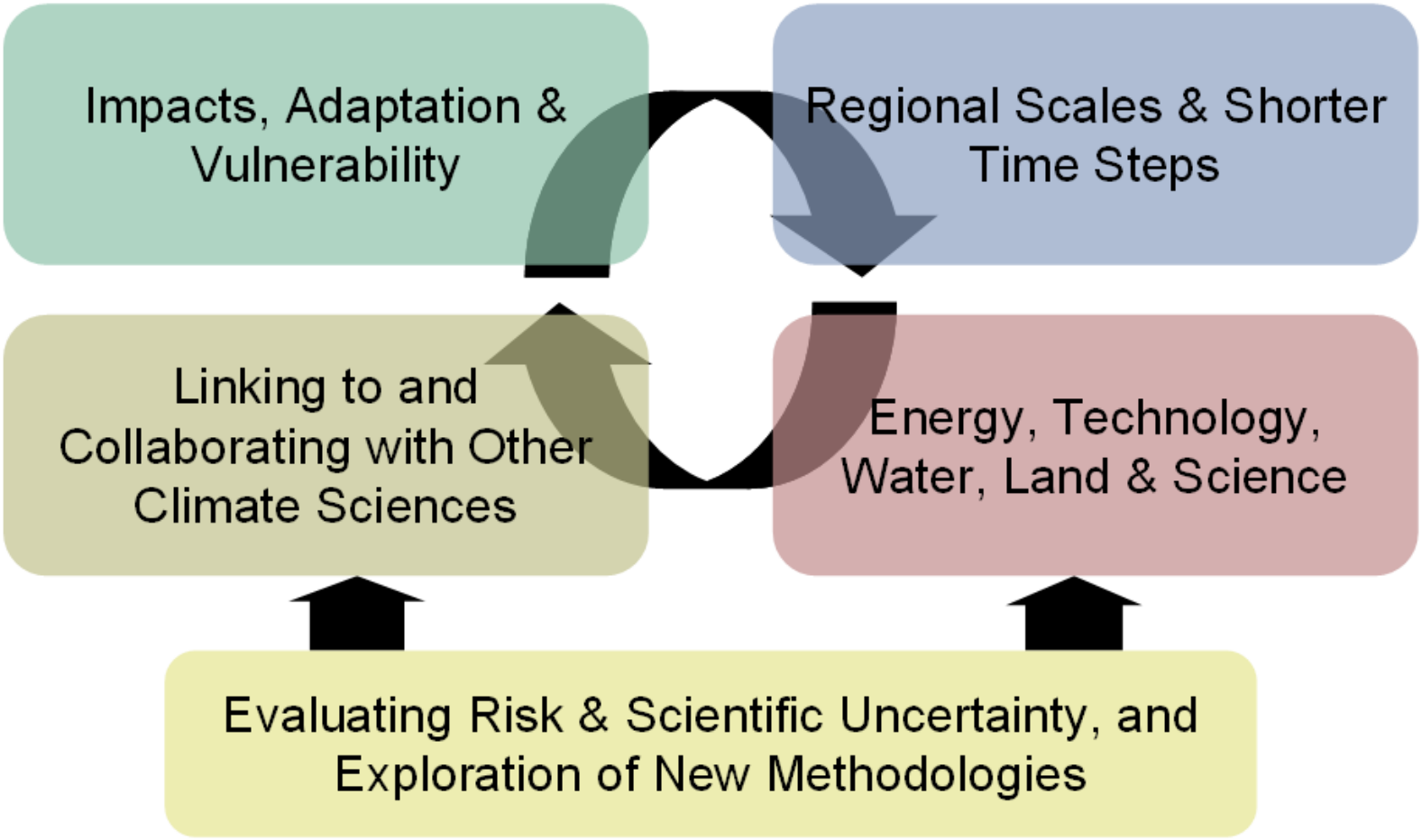
IAM Research Challenges



DISCUSSION