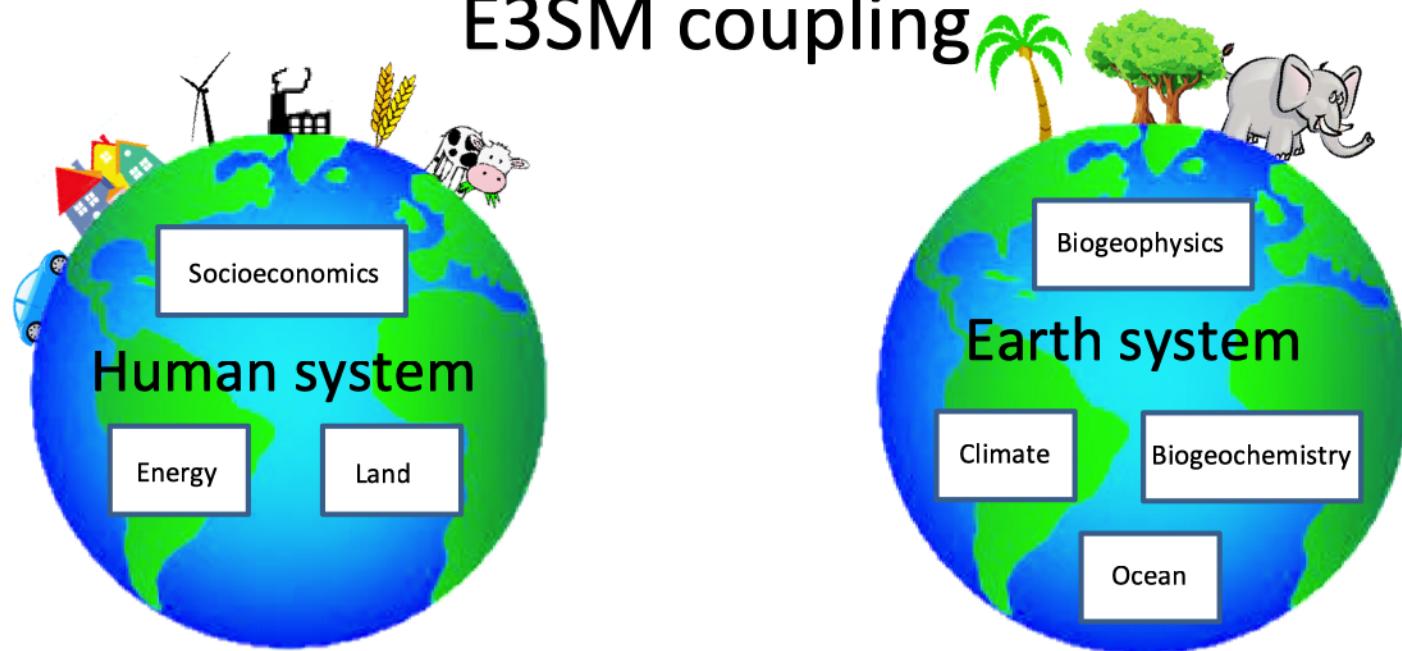


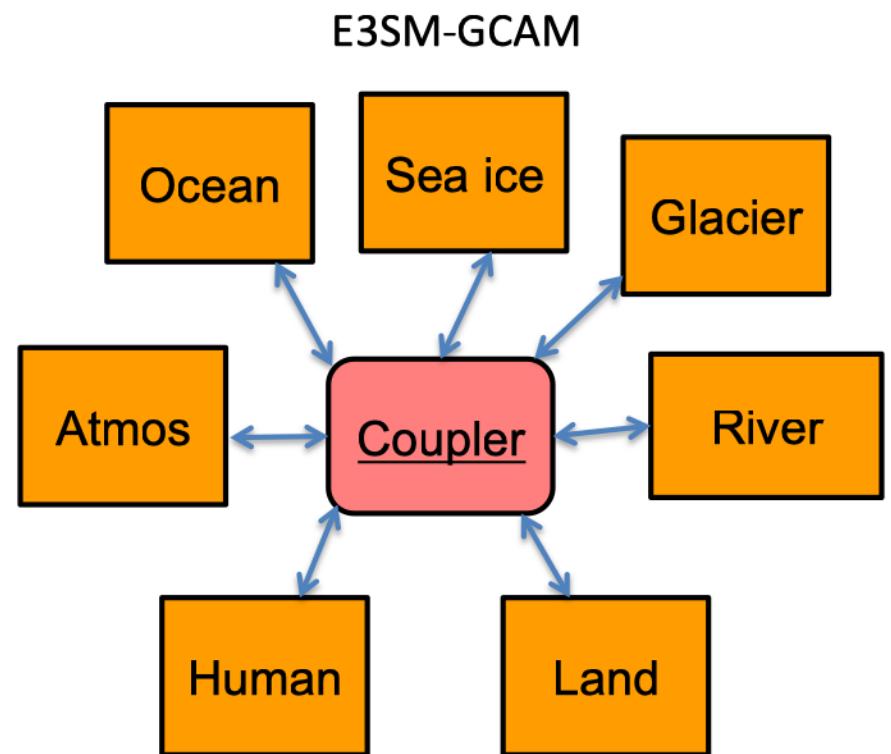
Modeling Human-Earth feedbacks: GCAM-E3SM coupling



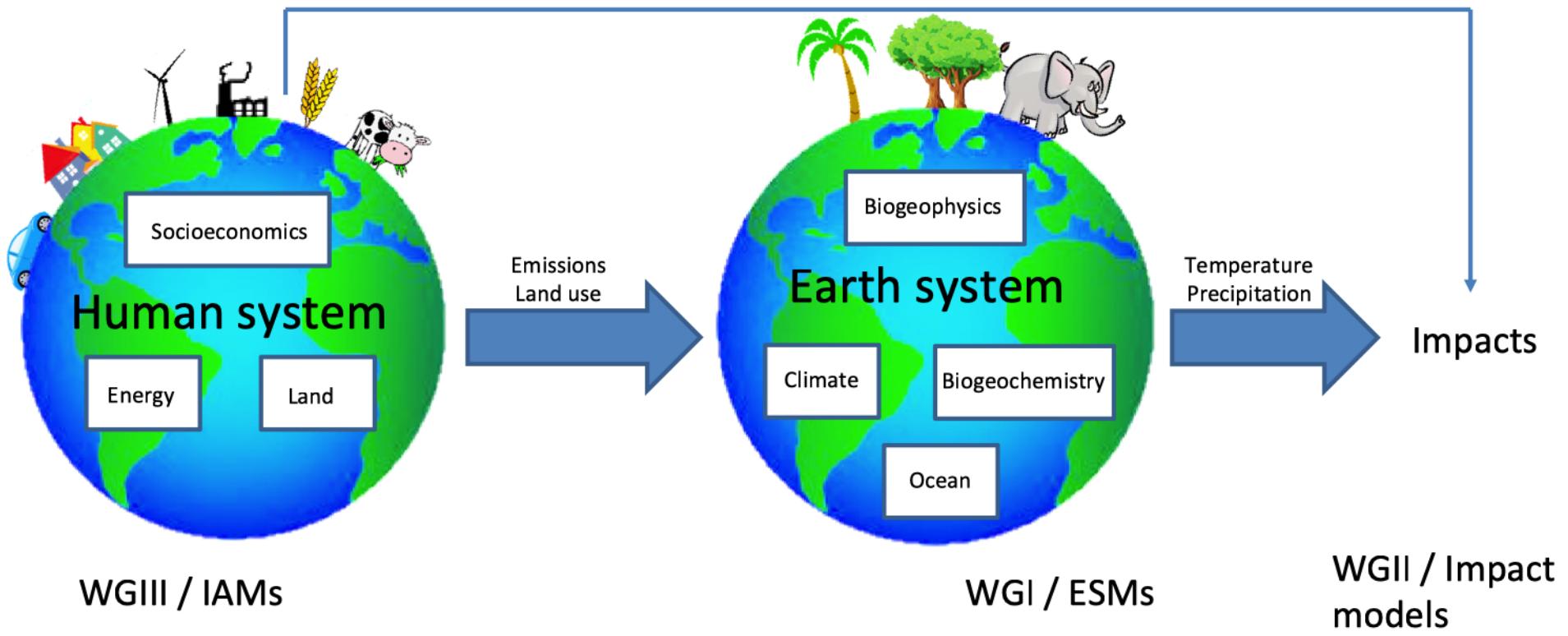
Alan Di Vittorio, Kate Calvin, Tim Shippert, Ben Bond-Lamberty

Overview

- Scenario-based modeling
- Consequences of Human-Earth feedbacks
- State of Human-Earth research
- E3SM-GCAM

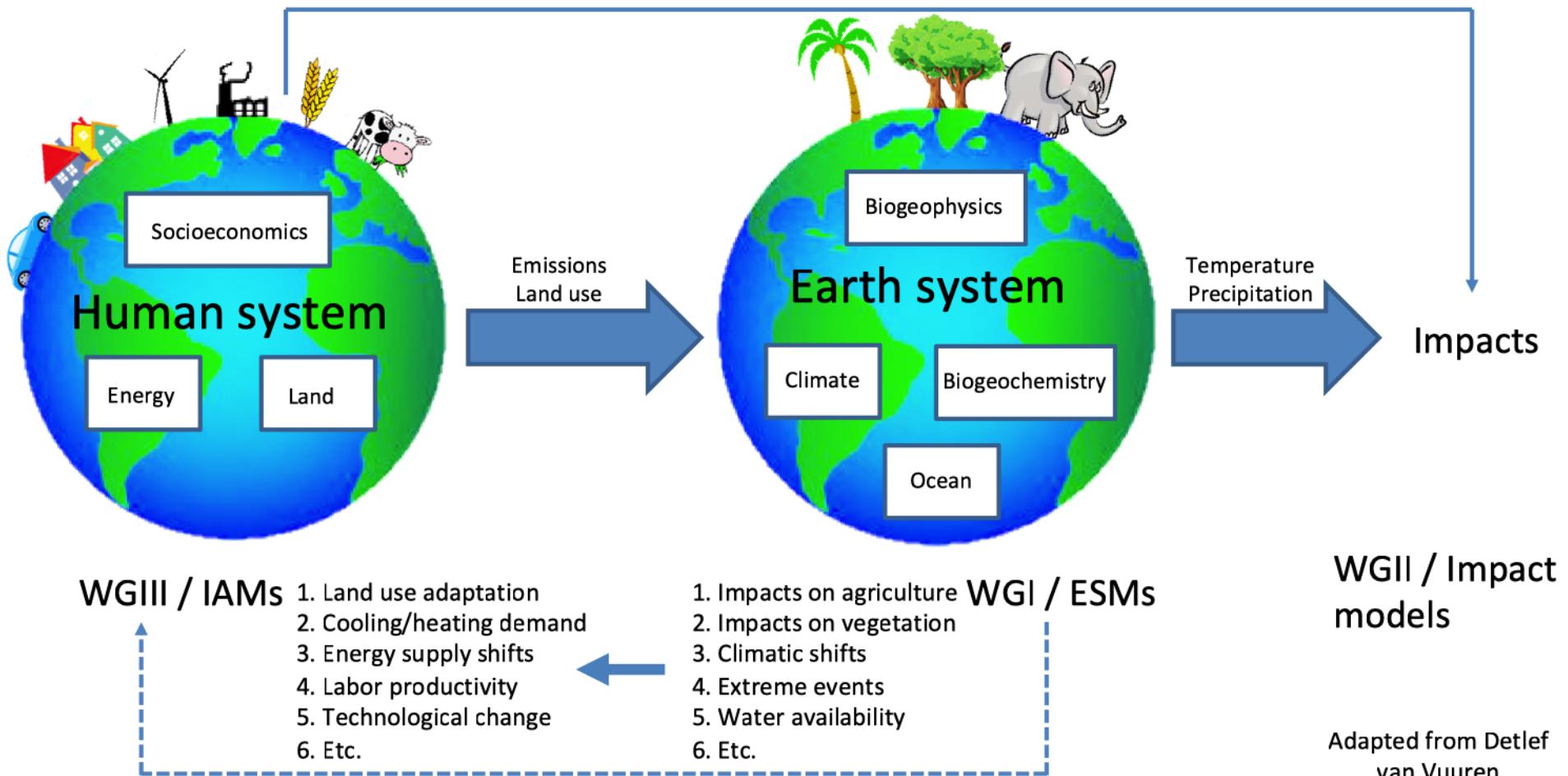


Current state of scenario-based modeling

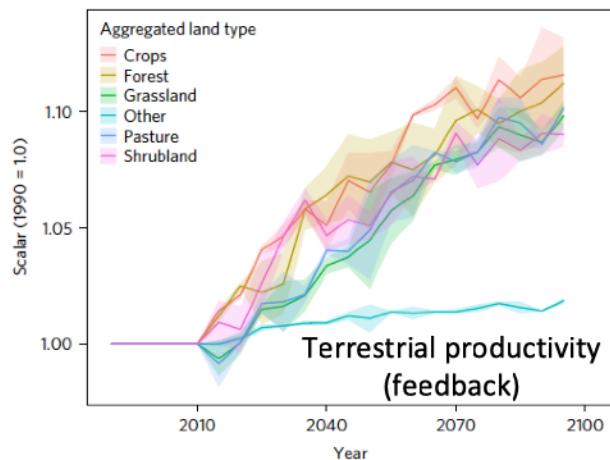


Adapted from Detlef
van Vuuren

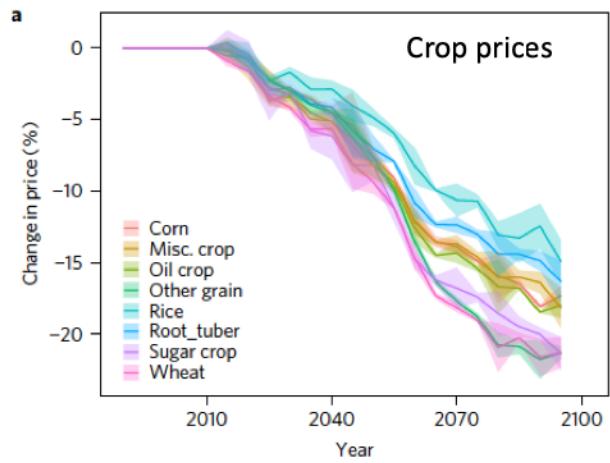
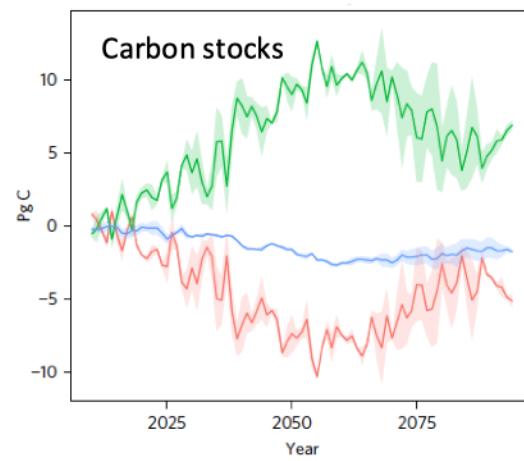
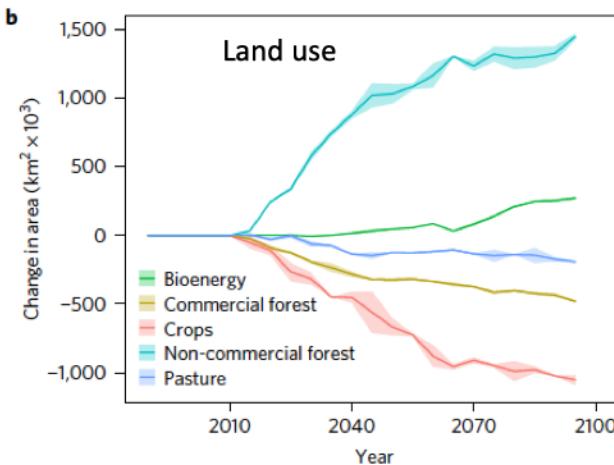
How do feedbacks disrupt the linear system?



Human-Earth feedbacks alter the scenario

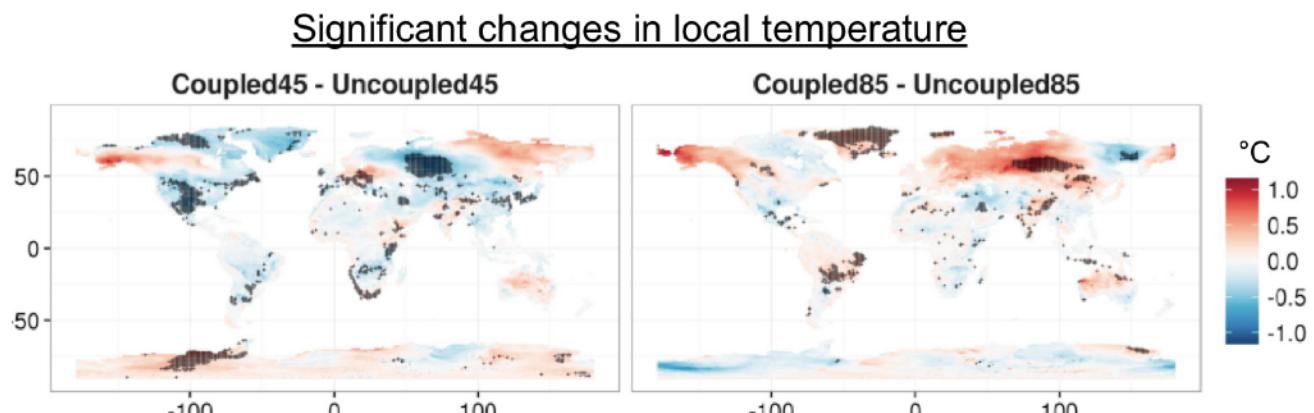
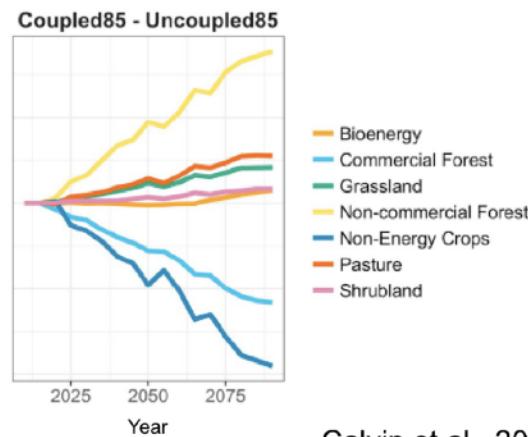
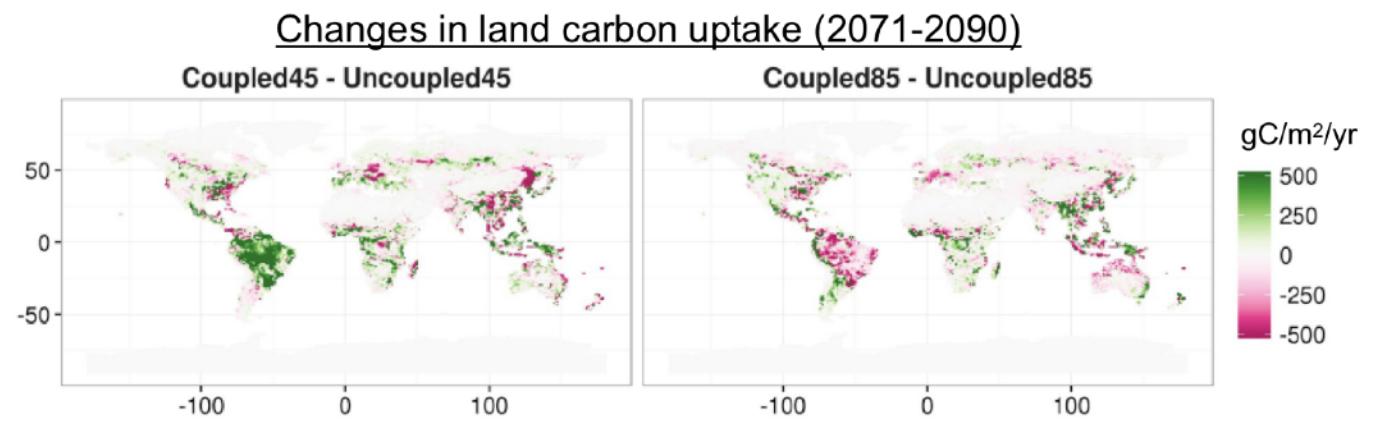
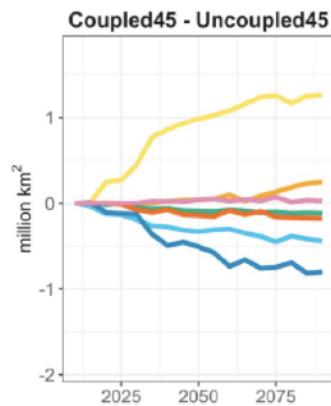


Effects of RCP 4.5
terrestrial feedbacks



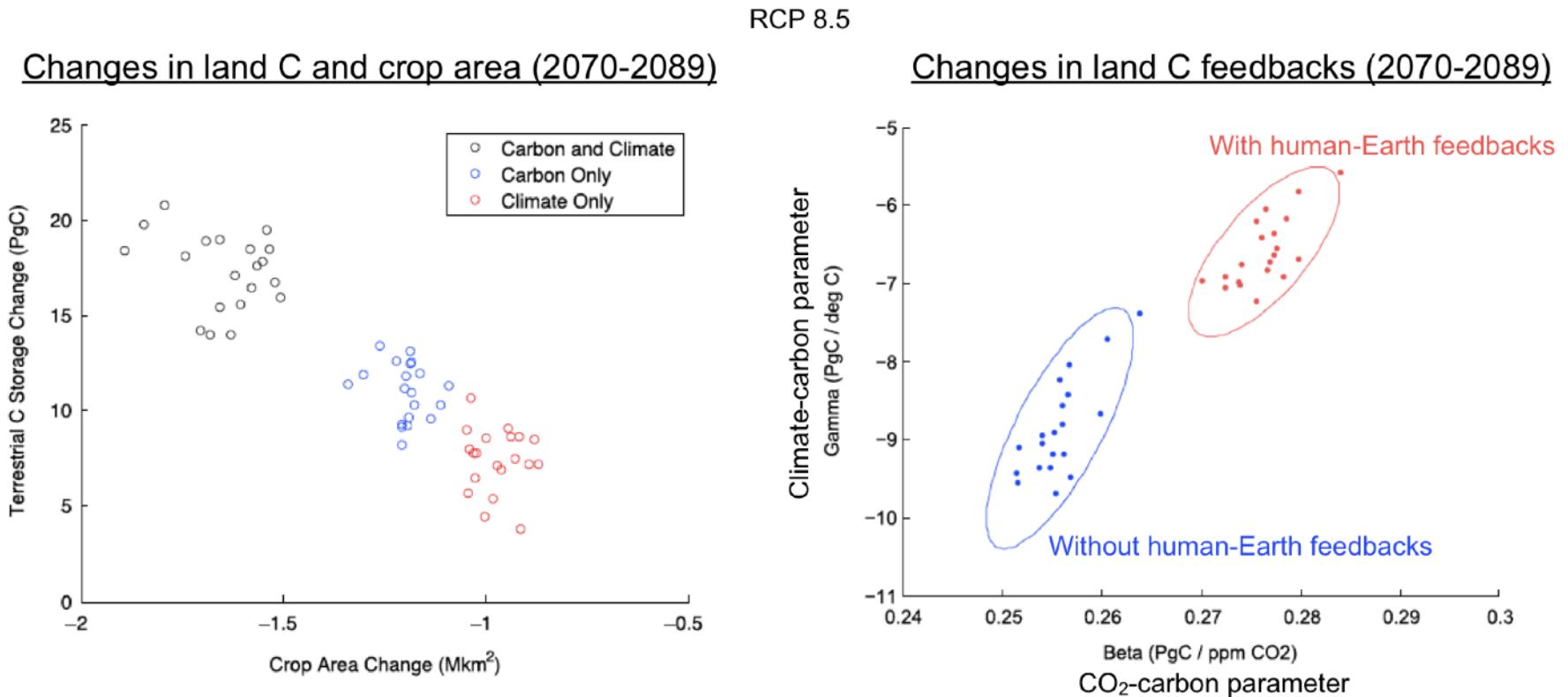
Thornton et al., 2017

Human-Earth feedbacks also affect carbon and temperature



Calvin et al., 2019

Human-Earth feedbacks also affect land carbon feedbacks



Jones et al., 2018

Growing area of research

Environ. Res. Lett. 7 (2012) 024012 (10pp)

doi:10.1088/1748-9326/7/2/024012

A comprehensive view on climate change: coupling of earth system and integrated assessment models

Received: 8 December 2017 | Revised: 28 December 2018 | Accepted: 18 January 2019
DOI: 10.1002/wcc.582

ADVANCED REVIEW

The use of the Community Earth System Model in human dimensions climate research and applications



Emily K. Laidlaw^{1,2*} | Brian C. O'Neill^{1,3*} | Ryan D. Harp^{4,5}

Modeling sustainability: population, inequality, consumption, and bidirectional coupling of the Earth and Human Systems

Safa Motesharrei^{1,*†}, Jorge Rivas^{2,†}, Eugenia Kalnay^{1,†}, Ghassem R. Asrar³,
Antonio J. Busalacchi⁴, Robert F. Cahalan^{5,6}, Mark A. Cane⁷,
Rita R. Colwell¹, Kuishuang Feng¹, Rachel S. Franklin⁸, Klaus Hubacek¹,
Fernando Miralles-Wilhelm^{1,3}, Takemasa Miyoshi^{1,9}, Matthias Ruth¹⁰,
Roald Sagdeev¹, Adel Shirmohammadi¹, Jagadish Shukla¹¹, Jelena Srebric¹,
Victor M. Yakovenko¹, and Ning Zeng¹

Methods and approaches to modelling the Anthropocene

Peter H. Verburg^{a,*}, John A. Dearing^b, James G. Dyke^b, Sander van der Leeuw^{c,h},
Sybil Seitzinger^d, Will Steffen^{e,f}, James Syvitski^g

Growing area of research

Modelling feedbacks between human and natural processes in the land system

Derek T. Robinson¹, Alan Di Vittorio², Peter Alexander^{3,4}, Almut Arneth⁵, C. Michael Barton⁶, Daniel G. Brown⁷, Albert Kettner⁸, Carsten Lemmen⁹, Brian C. O'Neill¹⁰, Marco Janssen¹¹, Thomas A. M. Pugh^{12,13}, Sam S. Rabin⁵, Mark Rounsevell^{3,5}, James P. Syvitski¹⁴, Isaac Ullah¹⁵, and Peter H. Verburg¹⁶

Environ. Res. Lett. 13 (2018) 063006

<https://doi.org/10.1088/1748-9326/aac642>

Environmental Research Letters

TOPICAL REVIEW

Integrated human-earth system modeling—state of the science and future directions

Katherine Calvin^{1,2}✉ and Ben Bond-Lamberty¹✉

Grand Challenges in Understanding the Interplay of Climate and Land Changes

Shuguang Liu,^{a,b} Ben Bond-Lamberty,^c Lena R. Boysen,^d James D. Ford,^e Andrew Fox,^f Kevin Gallo,^g Jerry Hatfield,^h Geoffrey M. Henebry,ⁱ Thomas G. Huntington,^j Zhihua Liu,^k Thomas R. Loveland,^b Richard J. Norby,^l Terry Sohl,^b Allison L. Steiner,^m Wenping Yuan,ⁿ Zhao Zhang,ⁿ and Shuqing Zhao^o

- 8) land-use modeling frameworks with uncertainty measures that capture all major biogeophysical, climatic, and socioeconomic forces of LCLUC and address feedbacks between processes operating at scales from local to global;

New organizations focused on Human-Earth modeling



The AIMES Modeling Earth System and Human interactions (MESH) Working Group

<https://aimesproject.org/mesh/>

Linking Human and Earth System Models for Global Change Analysis

JULY 19, 2021 TO JULY 21, 2021

Virtual Workshop

This workshop will bring together researchers working on a range of strategies to better understand the interactions and feedbacks between human and earth systems through improved linkages and coupled modeling of human and earth systems. Workshop themes include:

<https://www.agci.org/event/21s2>

The Open Modeling Foundation
Enabling next generation modeling of human and natural systems

About ⓘ Organization & Governance ➔ Standards ⓘ

<https://openmodelingfoundation.github.io>

Highlights of MESH workshop on linking Human and Earth system models for global change analysis

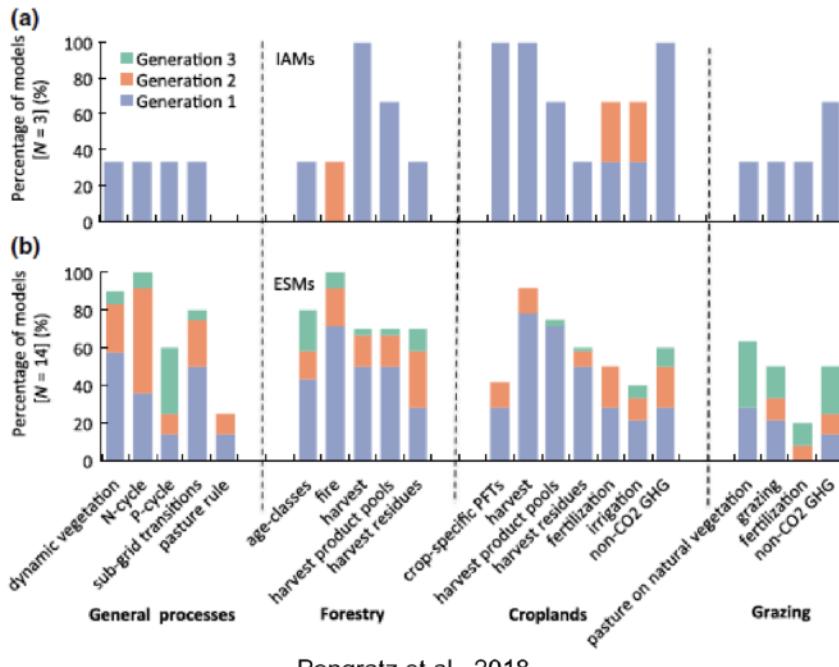
- Feedbacks are important, but not well understood
 - Some climate-sectoral relationships are better understood
 - Crops, energy, forest
- Critical development needs
 - Extreme events, **biodiversity**,
 - **human behavior**, bioenergy,
 - **policy conditions and response**
 - Multiple feedback approaches:
 - E.g., soft vs hard coupling
- Scenarios need expansion
 - Additional factors such as SDGs
 - Pathways vs targets
 - Shocks/disruptions
 - More scenarios
- Must reduce inconsistencies across models
 - Land use/cover
 - Agricultural practices
 - Forestry practices
 - Biogeophysics
 - Baselines and Definitions

Highly abstracted and condensed

IAM-ESM inconsistencies pose challenges

Carbon management is limited (and is only in IAMs)

Basic land management is increasing in implementation

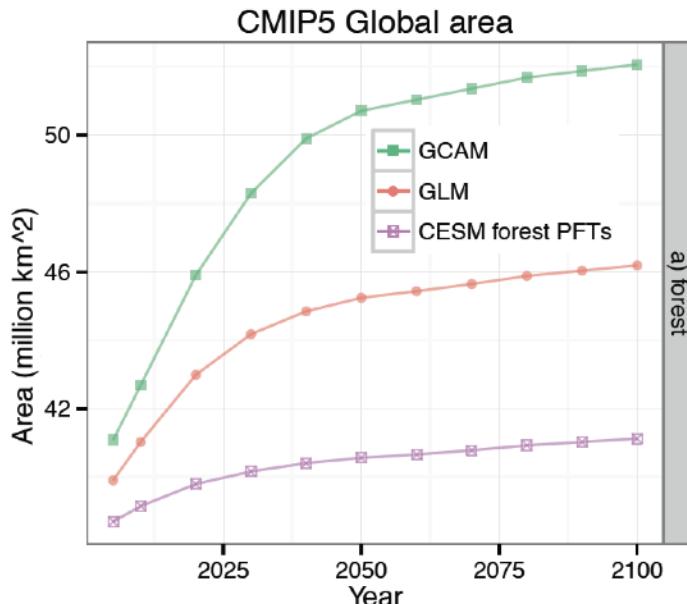


Levels of Inclusion		Model Names																				
	Explicit	Implicit	AIM	BET	COPPE-COFFEE	C-ROADS	DNE21+	GCM4.2	GEM-E3.0	GENESYSmod 1.0	GRAPE 1.0	IEA EIP	TEAWEM	IMAGCM 1.1	IMAGCM 3.2	MERGE-ETL 6.0	MESSAGE-GLOBIO	MESSAGE-GLOBIO-NL	POLES	REIND-MAGPIE	ShellWEM v1	WITCH
Endogenous	A	C																				
Exogenous	B	D																				
E	Not represented by model																					
Carbon Dioxide (Greenhouse Gas) Removal																						
B (t → BECCS)	A	A	A	D	A	A	F	A	A	A	A	A	A	A	A	A	B	A				
Direct air capture and sequestration (DACS) of CO ₂ , using chemical solvents and solid absorbents, with subsequent storage	E	E	F	D	E	E	F	E	E	E	E	E	E	E	E	E	E	E	E			
Mineralization of atmospheric CO ₂ through enhanced weathering of rocks	E	E	E	D	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E			
A (Forest expansion)	A	E	A	C	A	A	E	A	E	E	E	B	E	A	B	A	D	A				
Restoration of wetlands (e.g., coastal and peat-land restoration, blue carbon)	E	E	E	D	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E			
Biochar	E	E	E	D	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E			
Soil carbon enhancement, enhancing carbon sequestration in biota and soils, e.g. with plants with high carbon sequestration potential (also AFOLU measure)	E	E	E	D	E	E	E	E	E	E	E	E	D	E	A	B	C	E	E			
AFOLU Measures																						
R (Reduced deforestation)	A	E	A	D	B	A	E	E	B	D	D	E	B	B	E	A	B	A	D			
Forest management	C	E	E	D	E	C	E	E	C	D	D	E	B	B	E	A	B	E	D			
Reduced land degradation, and forest restoration	C	E	D	D	E	E	E	E	C	D	D	E	B	E	E	B	E	D	E			
Agroforestry and silviculture	E	E	D	D	E	E	E	E	F	D	D	E	E	E	E	E	E	E	E			
Urban and peri-urban agriculture and forestry	E	E	E	D	E	E	E	E	E	D	D	E	E	E	E	E	E	E	E			
Fire management and (ecological) pest control	C	E	D	D	E	C	E	E	E	D	D	E	E	E	E	E	E	E	E			
Changing agricultural practices that enhance soil carbon	C	E	E	D	E	E	E	E	E	D	D	E	E	E	E	E	B	E	D			
Conservation agriculture	E	E	E	D	E	E	E	E	E	D	D	E	E	E	E	A	E	E	C			
I (Increased ag productivity)	A	E	A	D	A	B	E	E	B	D	D	E	A	B	E	A	A	E	D			
Methane reductions in rice paddies	C	E	C	D	C	C	C	C	E	C	D	D	E	C	C	E	A	B	C			
Nitrogen pollution reductions (e.g., by fertilizer reduction, increasing nitrogen fertilizer efficiency, sustainable fertilizers)	C	E	C	D	C	C	C	C	E	D	D	E	A	C	E	A	A	B	C			
Livestock and grazing management, for example, methane and ammonia reductions in ruminants through feeding management or feed additives, or manure management for local biogas production to replace traditional biomass use	C	E	C	D	C	C	C	C	E	C	D	D	E	A	C	E	A	B	C			
Manure management	C	E	C	D	C	C	C	C	F	C	D	D	E	C	C	E	A	F	C			
Biophysical effects (I)	E	E	E	D	E	E	E	E	D	D	E	E	E	E	E	E	E	D	E			

Forster et al., 2018

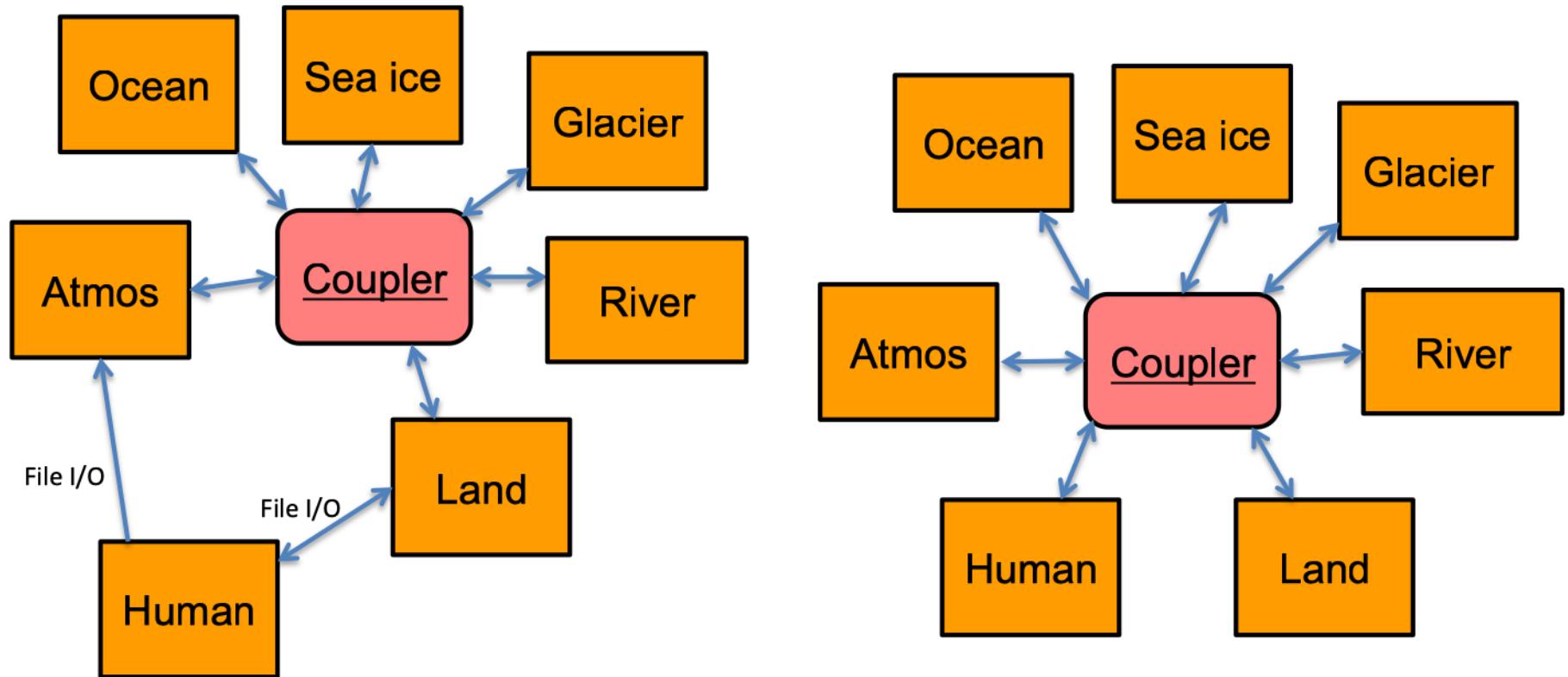
IAM-ESM inconsistencies pose challenges

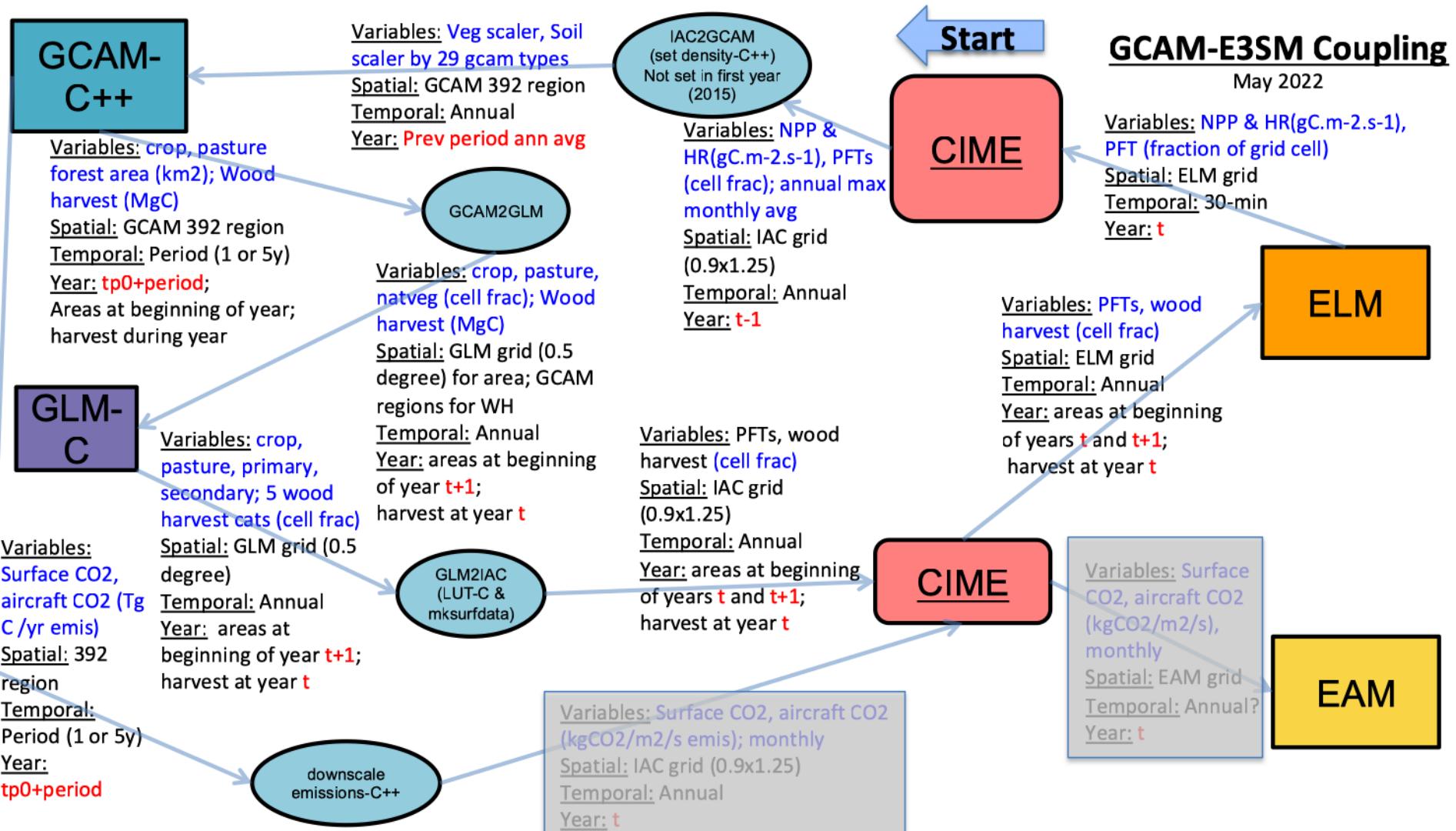
But existing processes are not yet
consistent across human-Earth modeling



Di Vittorio et al., 2014

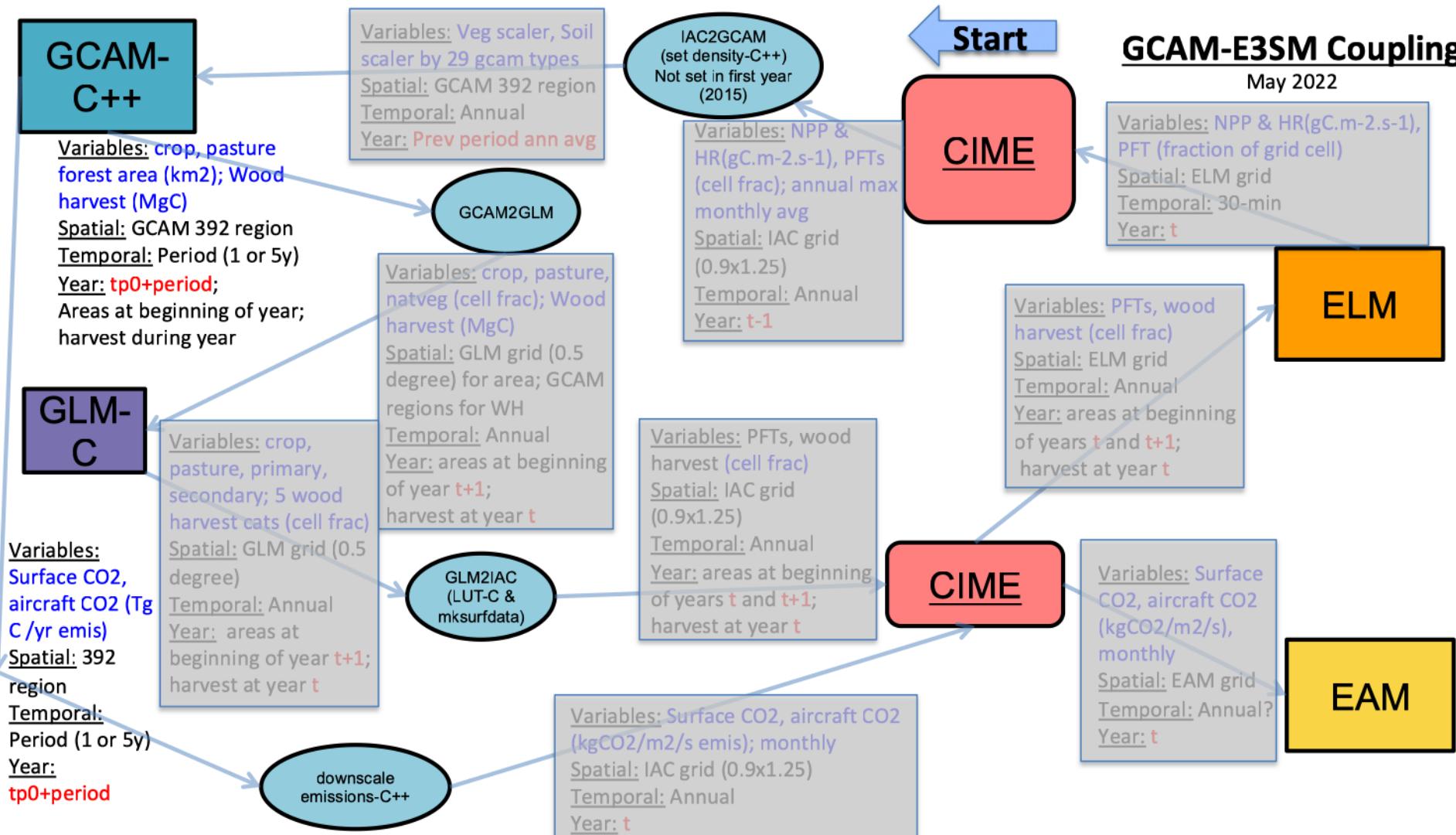
iESM vs E3SM-GCAM





GCAM-E3SM Coupling

May 2022



GCAM-E3SM Coupling

May 2022

