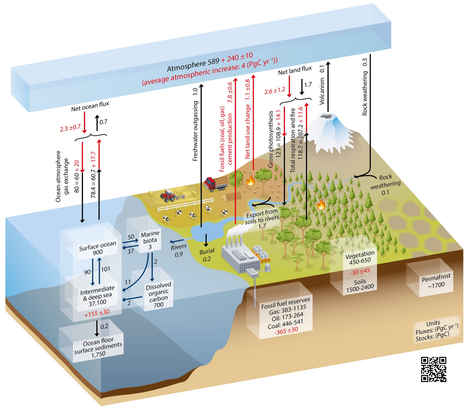
Carbon Cycle Feedbacks and the Social Cost of Carbon

Joseph Majkut, Robert Kopp*, Jorge Sarmiento, Thomas Frölicher†, Michael Oppenheimer
Princeton University, Princeton, NJ; * Rutgers University, New Brunswick, NJ; † ETH Zurich, Zurich, Switzerland

PEI PRINCETON ENVIRONMENTAL INSTITUTE

Carbon Cycle Feedbacks



Recent results compiled in the IPCC AR5 WG1 report indicate that carbon cycle feedbacks will positively reinforce climate warming. However, the magnitude of these feedbacks in Earth System Models is uncertain and decreased from IPCC AR4.

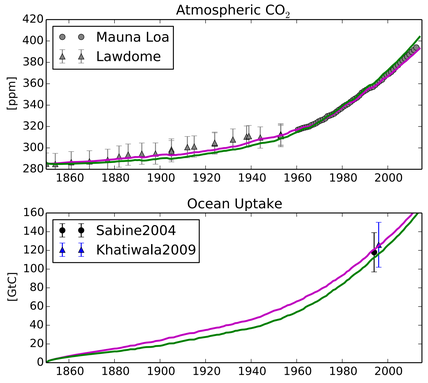
Feedback Examples (+ emits more CO_2):

- *Enhanced decomposition of soils and litter (+)*
- *CO2 fertilization of land photosynthesis (-)*
- *Warming of the surface ocean (+)*

Having models is one thing, but we want to see what recent observational records can tell us about the size of carbon cycle feedbacks.

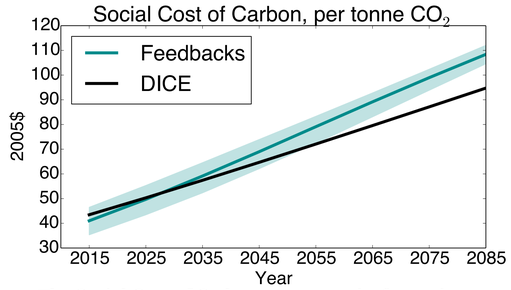
Learning about feedbacks

We use Markov-Chain Monte Carlo sampling to estimate the parameters of a simple carbon model using global observations of the carbon system. Fitting the model to measurements, in a way that properly treats uncertainty, allows us to examine the range of possible future states of the world when performing policy analysis.

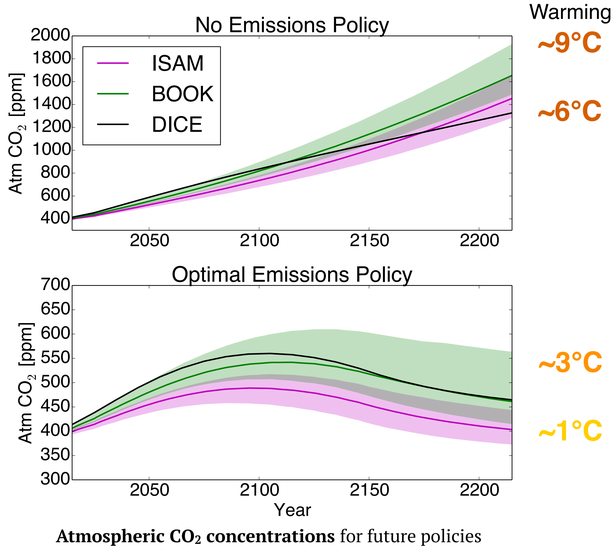


Results and Findings

Carbon Cycle Affects Policy Outcomes



The Social Cost of Carbon represents the future damages that will result from emissions. Here it is calculated for the post-learning carbon model and DICE2009 as in the US Federal Agencies guidance. The range of values for the carbon model represents the 5-95th percentile range.



Atmospheric CO_2 concentrations for future policies depend significantly on the strength of the carbon cycle feedbacks. Ranges here show the 5-95th percentile ranges for both LUC emissions cases. The black line shows the outcome for DICE2009.

Historical land use change (LUC) emissions

We use two estimates of the emissions from historical land use change. BOOK is a benchmark estimate widely used in the carbon cycle community based on historical forest inventories (Houghton 2012). ISAM is a newly released estimate based on model simulations (Jain 2013). Both are plausible, but the higher ISAM emissions require significantly weaker positive carbon cycle feedbacks, which reduces the burden on mitigation policy.

Learning Can Improve Policy Outcomes

Assuming a central decision maker is making climate policy with DICE and follows model outcomes, we can use new information about the carbon cycle feedbacks to improve policy outcomes.

(1) Including an active carbon cycle in the decision making yields a large improvement in policy outcome by reducing the mitigation burden early in policy.

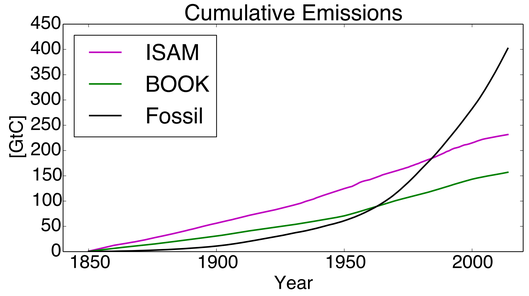
(2) Resolving the uncertainty in the carbon cycle feedback may prevent billions of dollars of increased damages or inefficient mitigation.

The improvement to policy increases substantially for a risk averse decision maker.

Net Consumption Benefit of Policy Transitions [2005$ trillion, billion]

Decreasing Risk Tolerance →

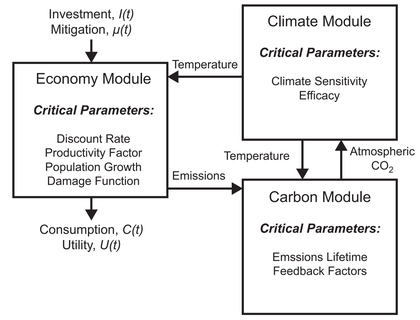
	(ρ=0.03, η=0)	(ρ=0.0125,η=1)	(ρ=0.006,η=1.4)	(ρ=-3e-3,η=2)	
Creating Policy and adding Carbon Cycle Feedbacks					
Adopting DICE2009 policy instead of no policy					
	71	**168**	**232**	**349**	
Using uncertain carbon model instead of DICE2009 Carbon					
	18	**18**	**17**	**15**	(1)
Refining Knowledge in Historical LUC					
Correctly identifying ISAM emissions case					
	123	*320*	*370*	*420*	(2)
Correctly identifying BOOK emissions case					
	130	*285*	*330*	*341*	



Dice Model

The DICE model[1] represents the interaction of the economy, the carbon cycle and the climate.

- CO_2 emissions are produced as an externality of economic activity and increase the atmospheric CO_2 concentration and temperature.
- Temperature warming has a negative impact on economic growth.
- Mitigation activity pays extra to reduce emissions.



We couple the uncertain carbon model to the climate and economy models within DICE to examine how carbon cycle feedbacks affect policy decisions and how learning can affect policy outcomes.

[1]Nordhaus, W. *The Climate Casino*, Yale University Press 2013

Future Learning

This framework provides a tool for further monitoring of the global carbon cycle and learning about carbon cycle feedbacks.

The potential policy benefits of learning about the carbon cycle, such as resolving the difference between the BOOK and ISAM LUC emissions, provide a use-based motivation for further inquiry.

Potential policy improvements may justify investments in monitoring systems for global carbon to enhance learning and to detect unexpected changes.

More Info

Contact jmajkut@princeton.edu for references and further information.