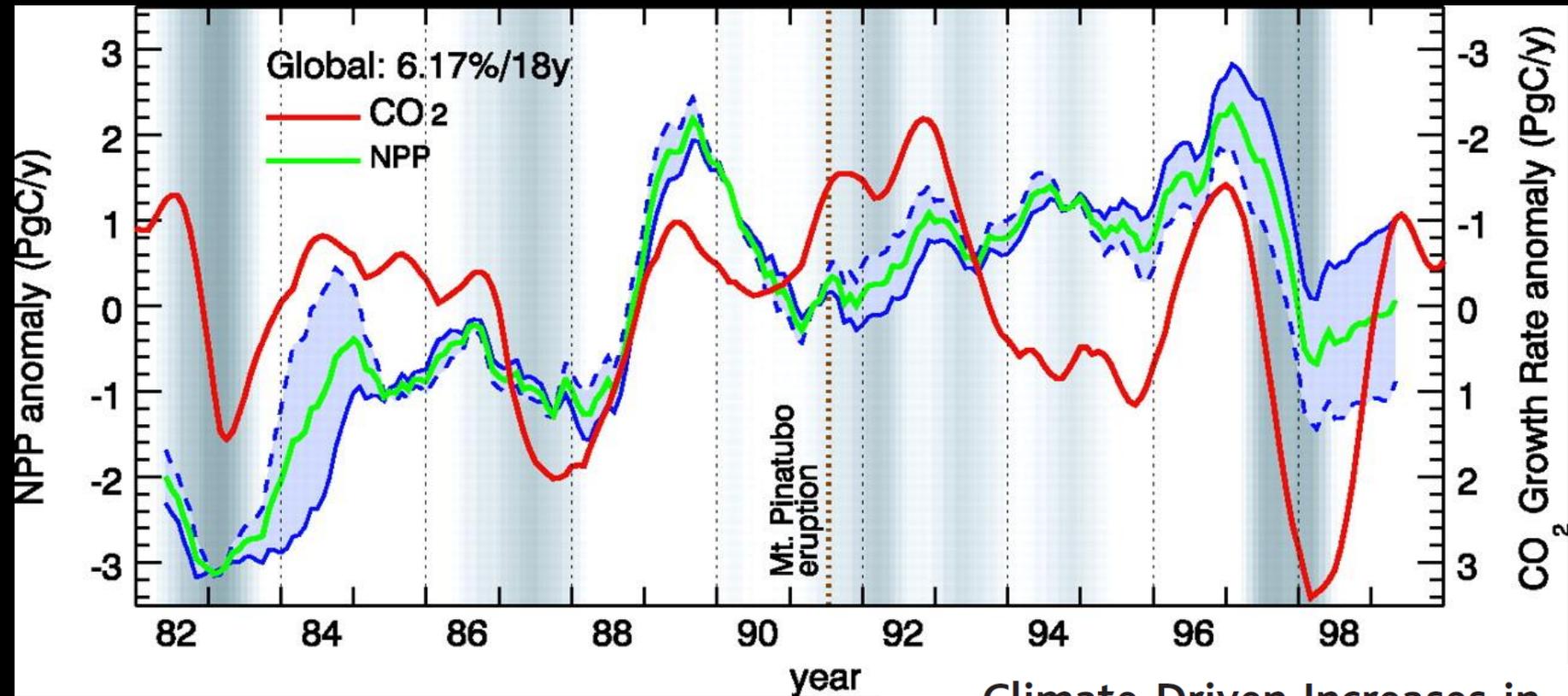


Attributing Changes in Gross Primary Productivity from 1901 to 2010

Christopher R Schwalm, Deborah N Huntzinger,
Anna M Michalak, Robert B Cook, Bassil El Masri,
Daniel J Hayes, Maoyi Huang, Andrew R Jacobson, Atul
K Jain, Huimin Lei, Chaoqun Lu, Hanqin Tian, Kevin M
Schaefer, and Yaxing Wei

Wednesday, 17 December 2014
The Emerging Science of Climate Attribution,
Detection, and Trend Analysis
2014 AGU Fall Meeting, San Francisco

For the times they are a-changin': Remote sensing



Climate-Driven Increases in Global Terrestrial Net Primary Production from 1982 to 1999

Ramakrishna R. Nemani,^{1*} Charles D. Keeling,²
Hirofumi Hashimoto,^{1,3} William M. Jolly,¹ Stephen C. Piper,²
Compton J. Tucker,⁴ Ranga B. Myneni,⁵ Steven W. Running¹

Through prism of NPP, i.e., “taxed” GPP
± 3 PgC/yr IAV

For the times they are a-changin': Upscaled FLUXNET

Data oriented approach

FLUXNET (c. 250 sites)

+

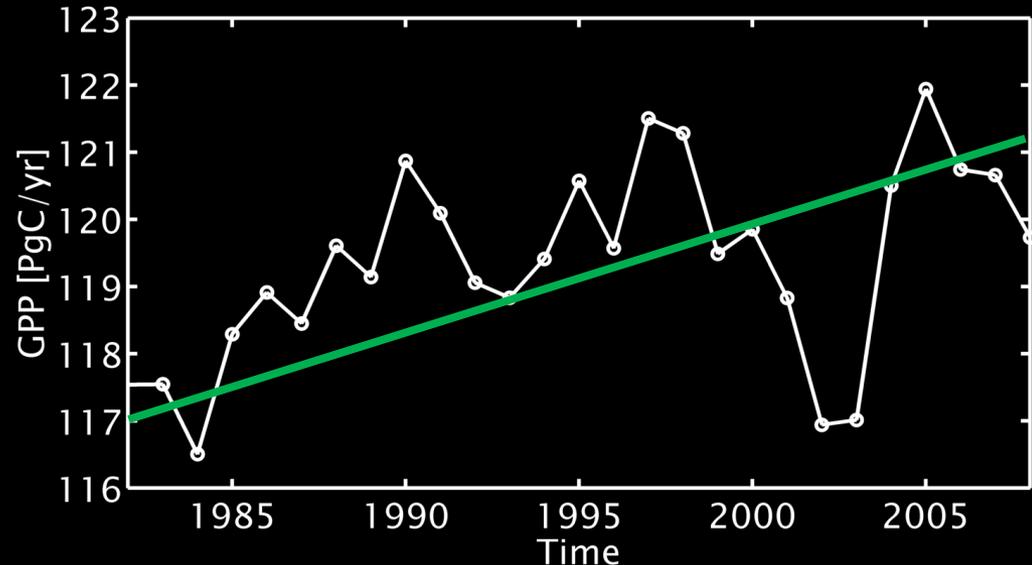
Ancillary data (fAPAR, meteo, PFT)

+

Machine learning

=

Global gridded maps (1982-2008)

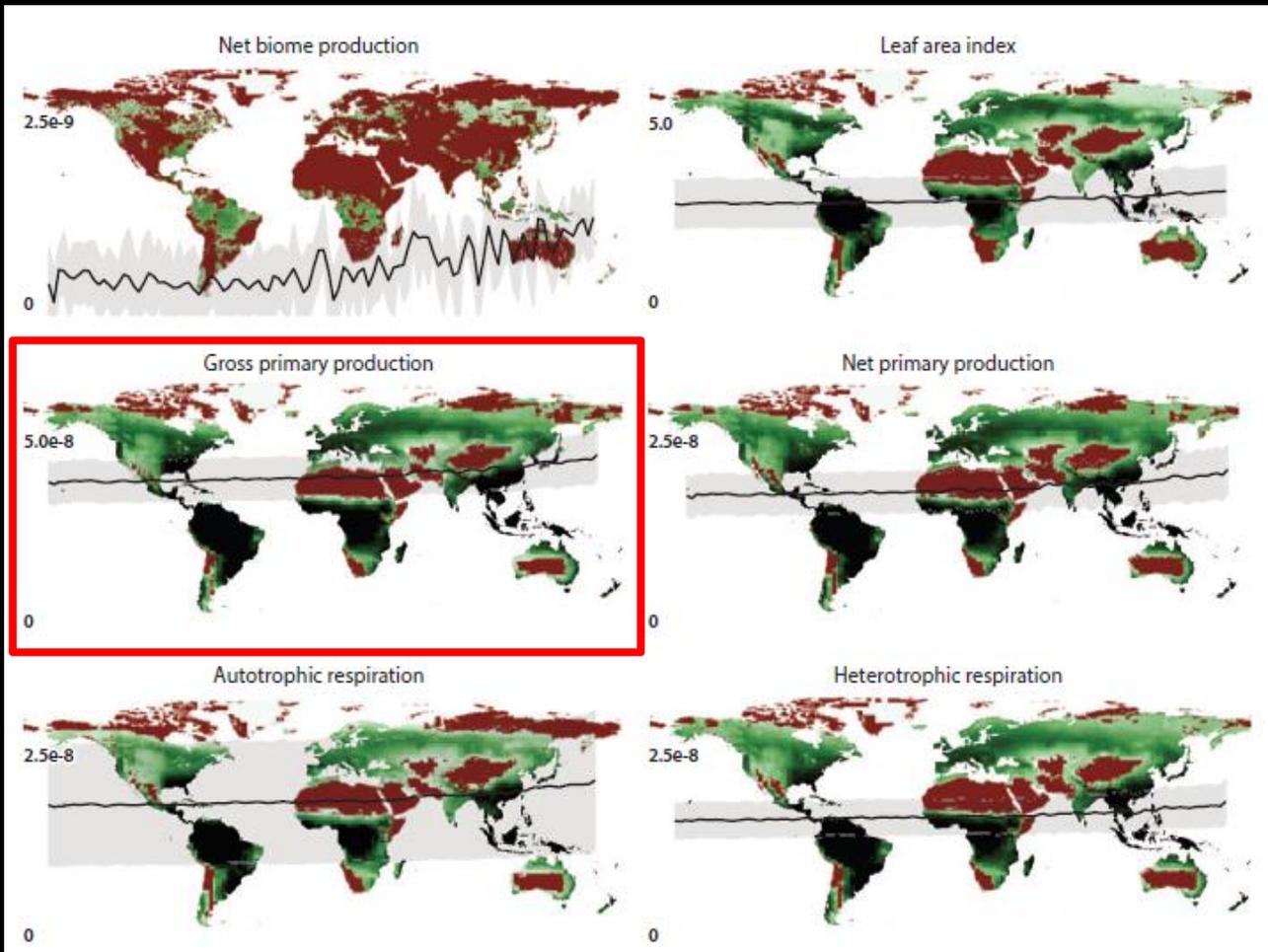


Global patterns of land-atmosphere fluxes of carbon dioxide, latent heat, and sensible heat derived from eddy covariance, satellite, and meteorological observations

Martin Jung,¹ Markus Reichstein,¹ Hank A. Margolis,² Alessandro Cescatti,³ Andrew D. Richardson,⁴ M. Altaf Arain,⁵ Almut Arneeth,^{6,7} Christian Bernhofer,⁸ Damien Bonal,⁹ Jiquan Chen,¹⁰ Damiano Gianelle,¹¹ Nadine Gobron,¹² Gerald Kiely,¹³ Werner Kutsch,¹⁴ Gitta Lasslop,¹ Beverly E. Law,¹⁵ Anders Lindroth,⁶ Lutz Merbold,¹⁶ Leonardo Montagnani,^{17,18} Eddy J. Moors,¹⁹ Dario Papale,²⁰ Matteo Sottocornola,¹¹ Francesco Vaccari,²¹ and Christopher Williams²²

Received 30 September 2010; revised 18 May 2011; accepted 6 June 2011; published 3 September 2011.

For the times they are a-changin': Terrestrial biosphere modeling



Modeling the Terrestrial Biosphere

Joshua B. Fisher,¹ Deborah N. Huntzinger,^{2,3}
Christopher R. Schwalm,² and Stephen Sitch⁴

MIP

TRENDY

1901-2010

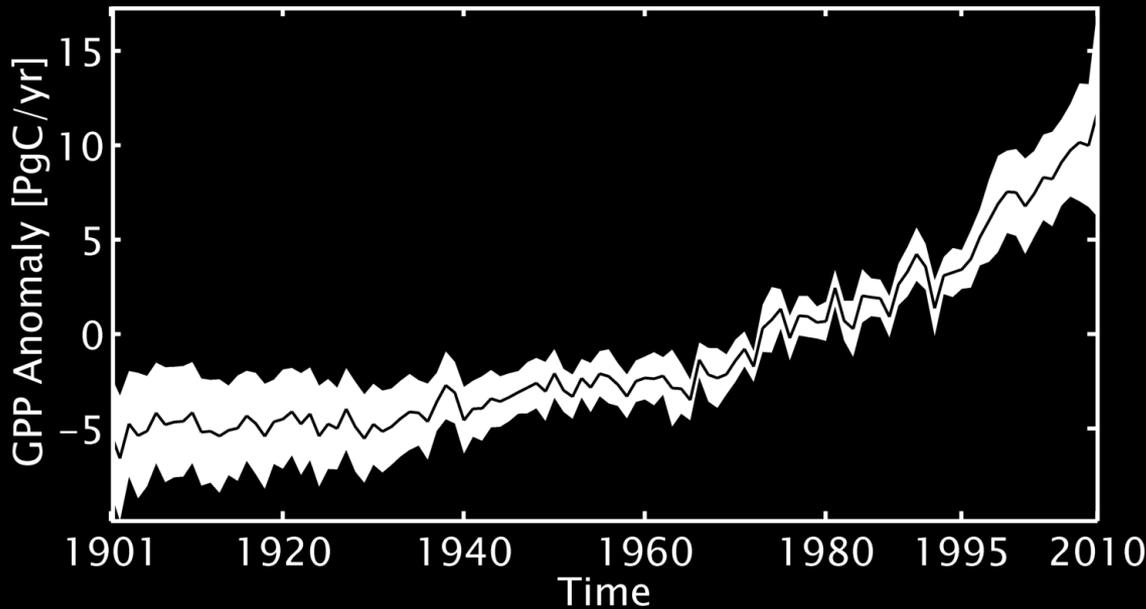
Ensemble mean

Varying CO₂ and climate

Constant land use

Mean global GPP → c. 135
gC m⁻² mo⁻¹

For the times they are a-changin': Terrestrial biosphere modeling



GPP Anomaly over Time
Black lines: ensemble mean
White envelope: ensemble range

MIP

MsTMIP

1901-2010

Ensemble mean ($n = 5$)

Varying climate, CO₂, land use/land cover,
nitrogen deposition

North American Carbon Program
MsTMIP NASA
MULTI-SCALE SYNTHESIS AND TERRESTRIAL MODEL INTERCOMPARISON PROJECT

MsTMIP Global Simulation Results version 1.0

[MsTMIP Product Use and Co-Authorship Policy](#)

[MsTMIP Participants and Contact Info](#)

[MsTMIP Version 1 Screening](#)

[Contact us](#)

What has driven the changes in GPP?

Attribution Framework

- Historical reconstructions of GPP
- Reconstructions taken from MsTMIP
- Dual approach
 - Differencing
 - Machine learning
- Causal factors: T_{air} , precipitation, SW_{\downarrow} , LULCC, $[CO_2]$, N deposition, nonlinearity, σ_{climate}

MsTMIP Simulations

Reference simulation → spin-up run out to 2010

Order	Domain	Code	Climate	LULCC	[CO ₂]	Nitrogen
1	Global 	RG1	Constant	Constant	Constant	Constant
2		SG1	Time-varying (CRU+NCEP)			
3		SG2		Time-varying (Hurtt)		
4		SG3			Time-varying	
5		BG1		Time-varying		

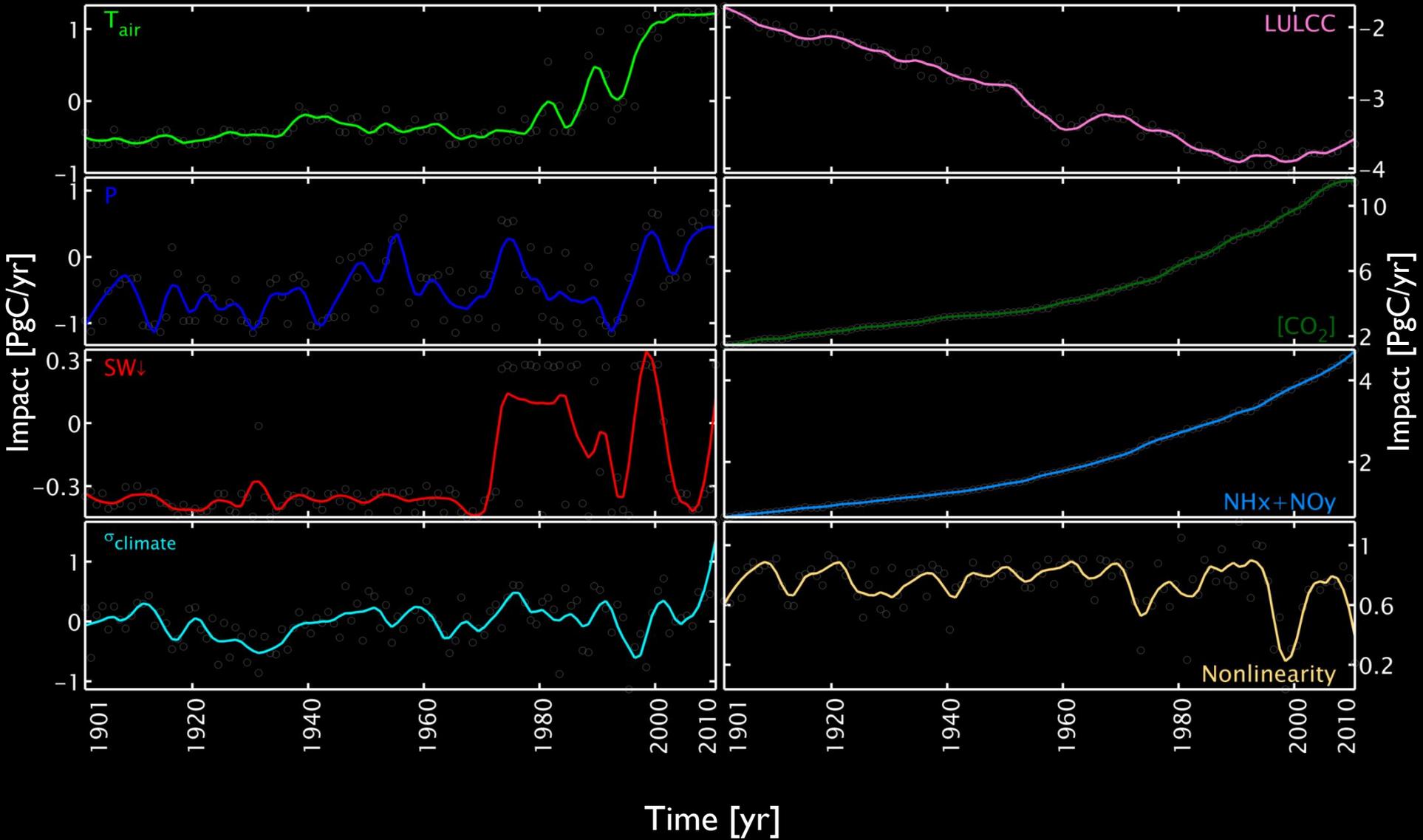
Sensitivity simulations → model's response to component perturbations to carbon system (mainly test the impact of climate variability, CO₂ fertilization, nitrogen limitation and land cover / land-use change on carbon exchange).

Effect of nitrogen limitation → SG3
 Effect of CO₂ fertilization → SG2
 Effect of land cover / land-use change → SG1

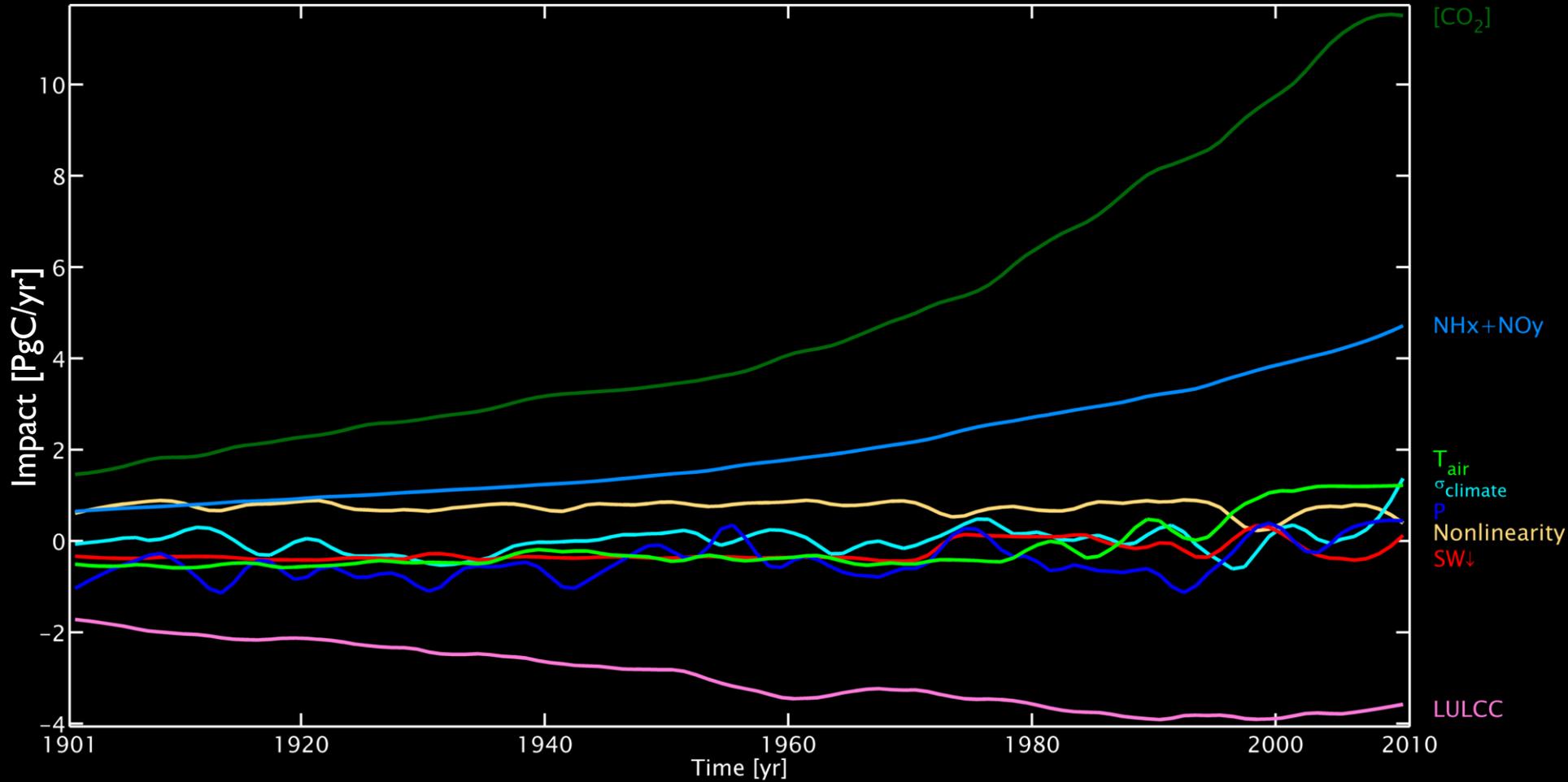
Attribution Framework

- Attribution based on historical reconstructions of gross primary productivity
- Reconstructions taken from MsTMIP
- Dual approach
 - Differencing
 - Machine learning
- Causal factors: T_{air} , precipitation, SW_{\downarrow} , LULCC, $[\text{CO}_2]$, N deposition, nonlinearity, σ_{climate}

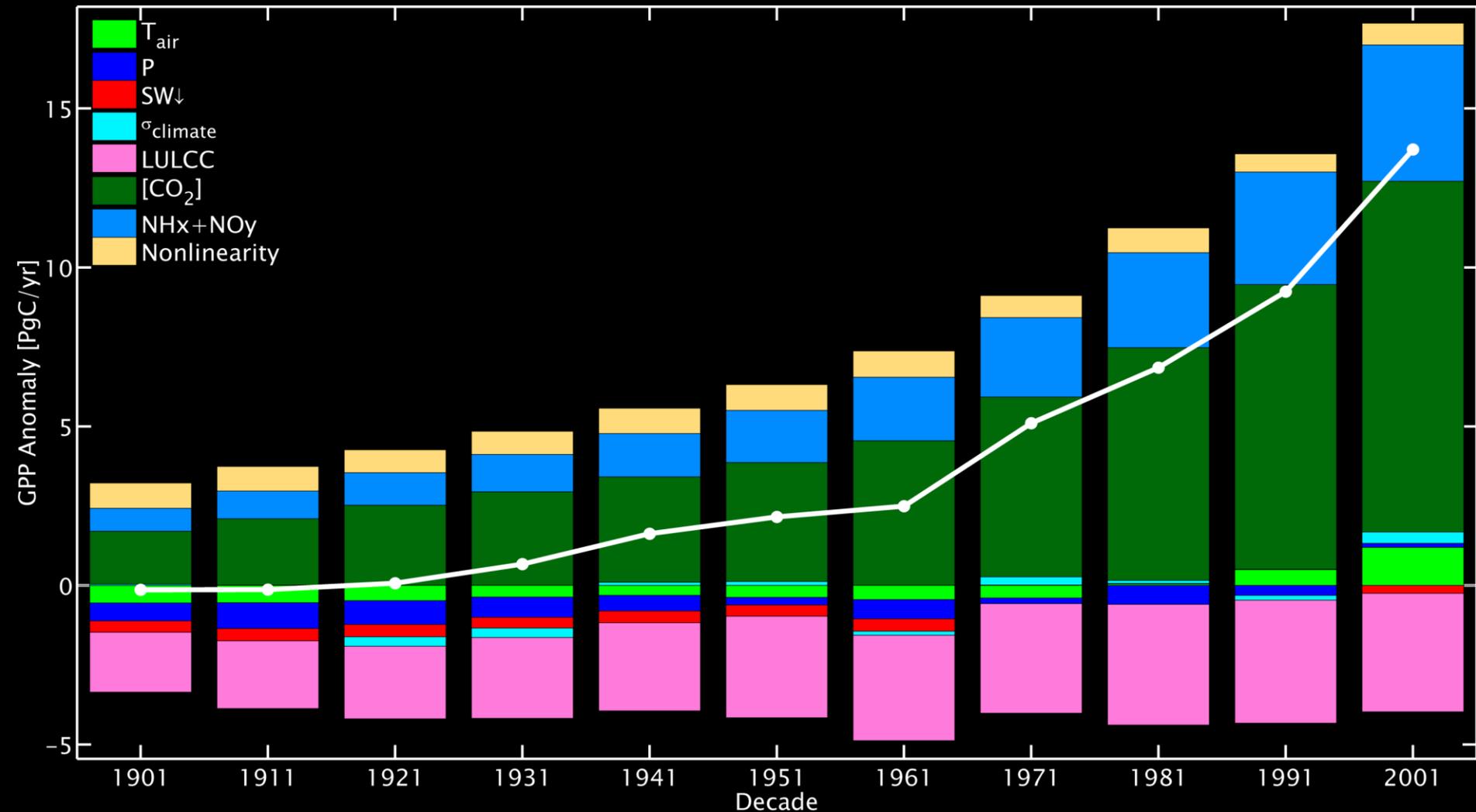
Act Causal



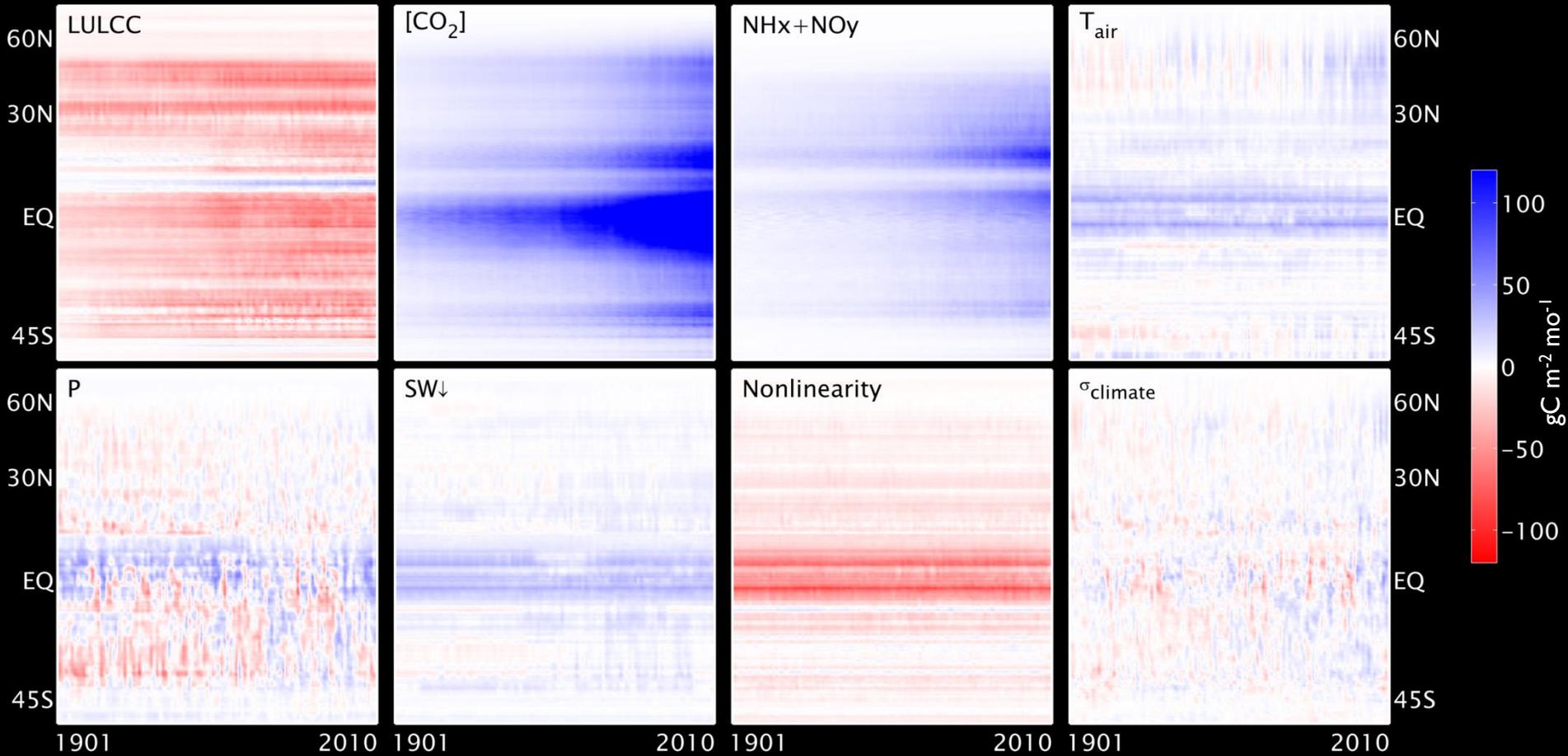
Factor v. Factor



Decadal GPP Partitioned



Hovmöller: Space v. Time



Summary

- Differencing and machine-learning method to map change to discreet drivers
- 2/3 of global warming since 1975 but [CO₂] as most dominant driver since 1901
 - [CO₂] fingerprint emerges in the tropics but exists across all latitudinal bands
- Nitrogen deposition v. LULCC in balance
- Human agency >> climate
 - Remaining factors largely stationary “noise”
 - Only [CO₂], nitrogen deposition, and LULCC show non-stationarity viz. secular trends

Acknowledgements

NASA Grants **NNX12AP74G**, **NNX10AG01A**, and **NNX11AO08A**

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MsTMIP Version I available to the scientific community at:

http://nacp.ornl.gov/mstmipdata/mstmip_simulation_results_global_v1.jsp

MsTMIP Phase II PhD student needed! Scientific focus: diagnosing inter-model spread; climate extremes; mapping skill to structure; forward simulation (to 2100); “big data”

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