Regionally strong feedbacks between the atmosphere and terrestrial biosphere

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CONFESS GENERAL ASSEMBLY

DECEMBER 1, 2021

Talk layout

- Research Motivation
- Research Question and Objectives
- Research Project 1: Biosphere-atmosphere feedbacks

Research Motivation

- Climate changes are threatening nations worldwide

Research Motivation

NOVEMBER 10, 2021

Climate change study says Vermont is getting warmer and wetter

Canada's flood havoc after summer heatwave shows how climate disasters combine to do extra damage

Climate-induced sea level rise threaten coastal communities and could get worse

Hotter Summer Days Mean More Sierra Nevada Wildfires, Study Finds

Climate change puts stress on Northwest forests in fire season

Research Motivation

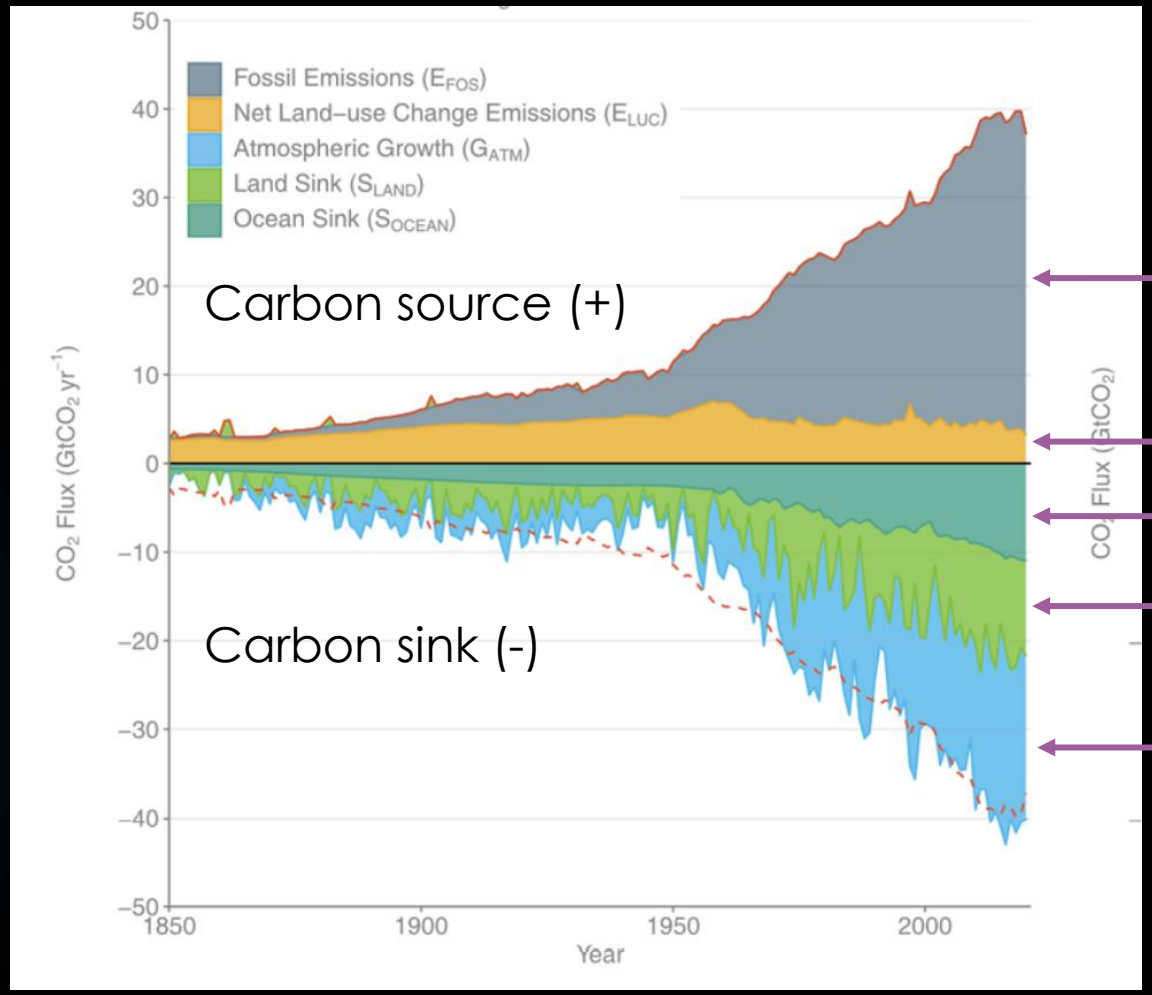
ASK NASA CLIMATE | November 8, 2021, 08:02 PST

Extreme Makeover: Human Activities Are Making Some Extreme Events More Frequent or Intense

By Alan Buis,
NASA's Jet Propulsion Laboratory

Research Motivation

Research Motivation



Fossil Emissions

Land-use Emissions

Ocean Sink

Land Sink

Atmospheric Growth rate

Friedlingstein, et al. Global Carbon Budget 2021. 2021.

Research Motivation

ASK NASA CLIMATE | November 8, 2021, 08:02 PST

Extreme Makeover: Human Activities Are Making Some Extreme Events More Frequent or Intense

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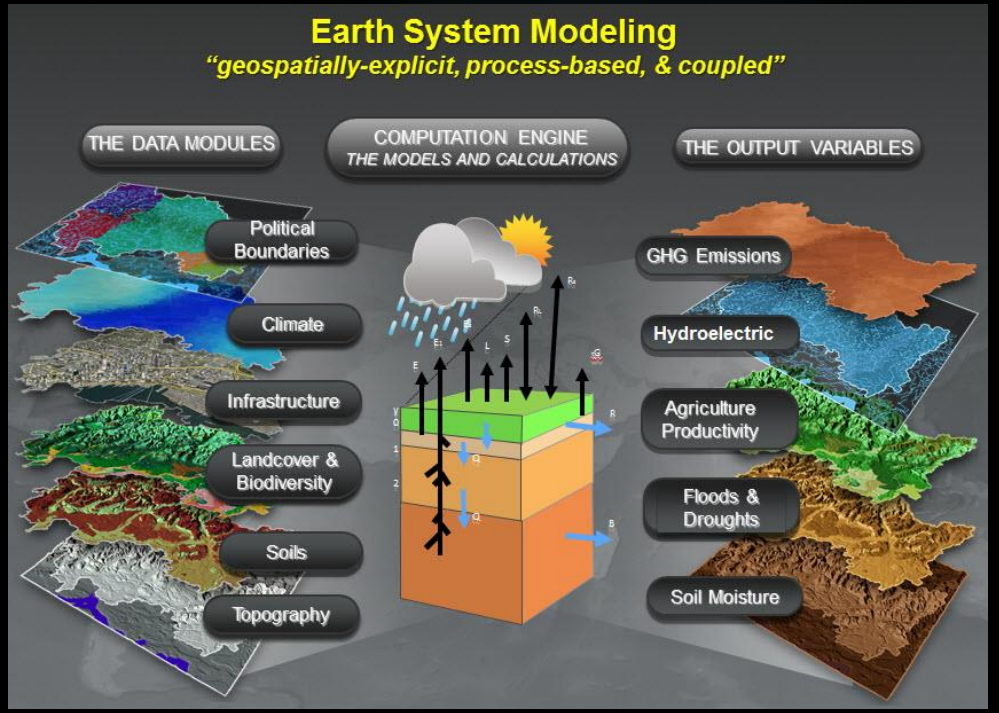
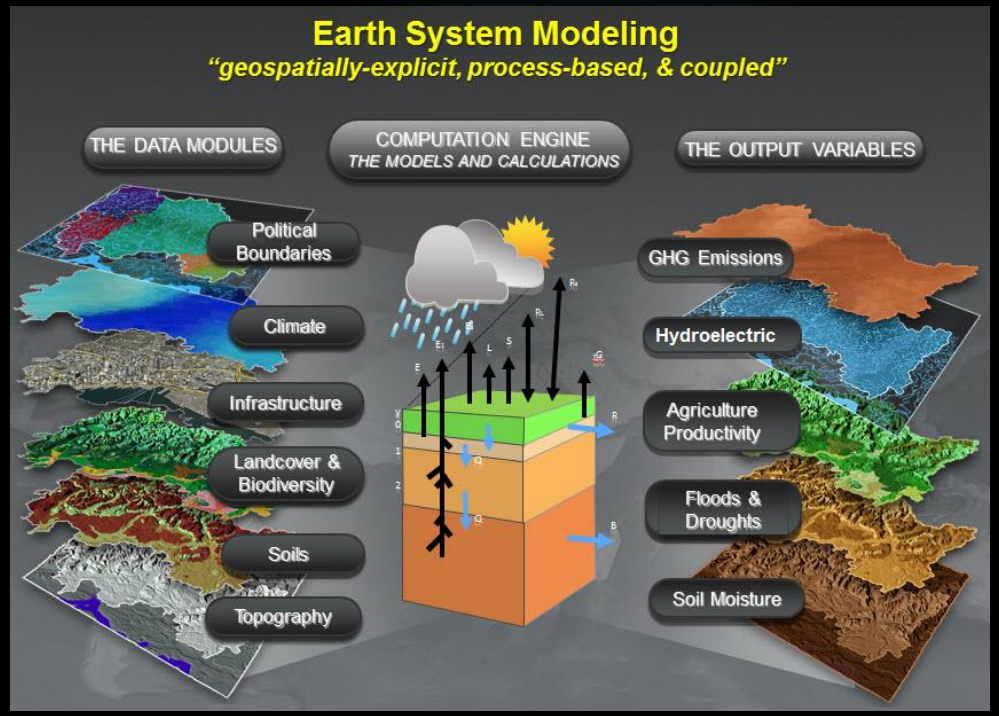
Research Question and Objectives

- How can we improve the science, to improve our projections?



Research Question and Objectives

- Understand mechanistically what is going on now, and improve our understanding of
  - Biosphere-atmosphere feedbacks (vegetation)
  - Vegetation sensitivity to water stress
- Provide insight for model improvement
  - Benchmarking
  - Identifying model representation that needs improvement

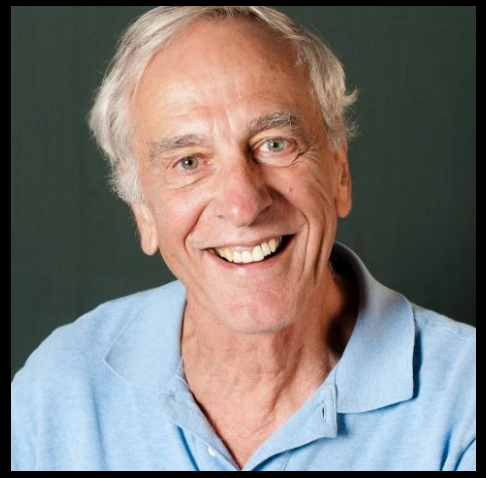
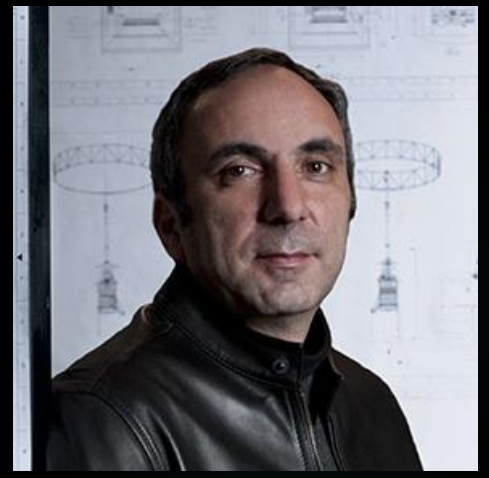


Project 1:

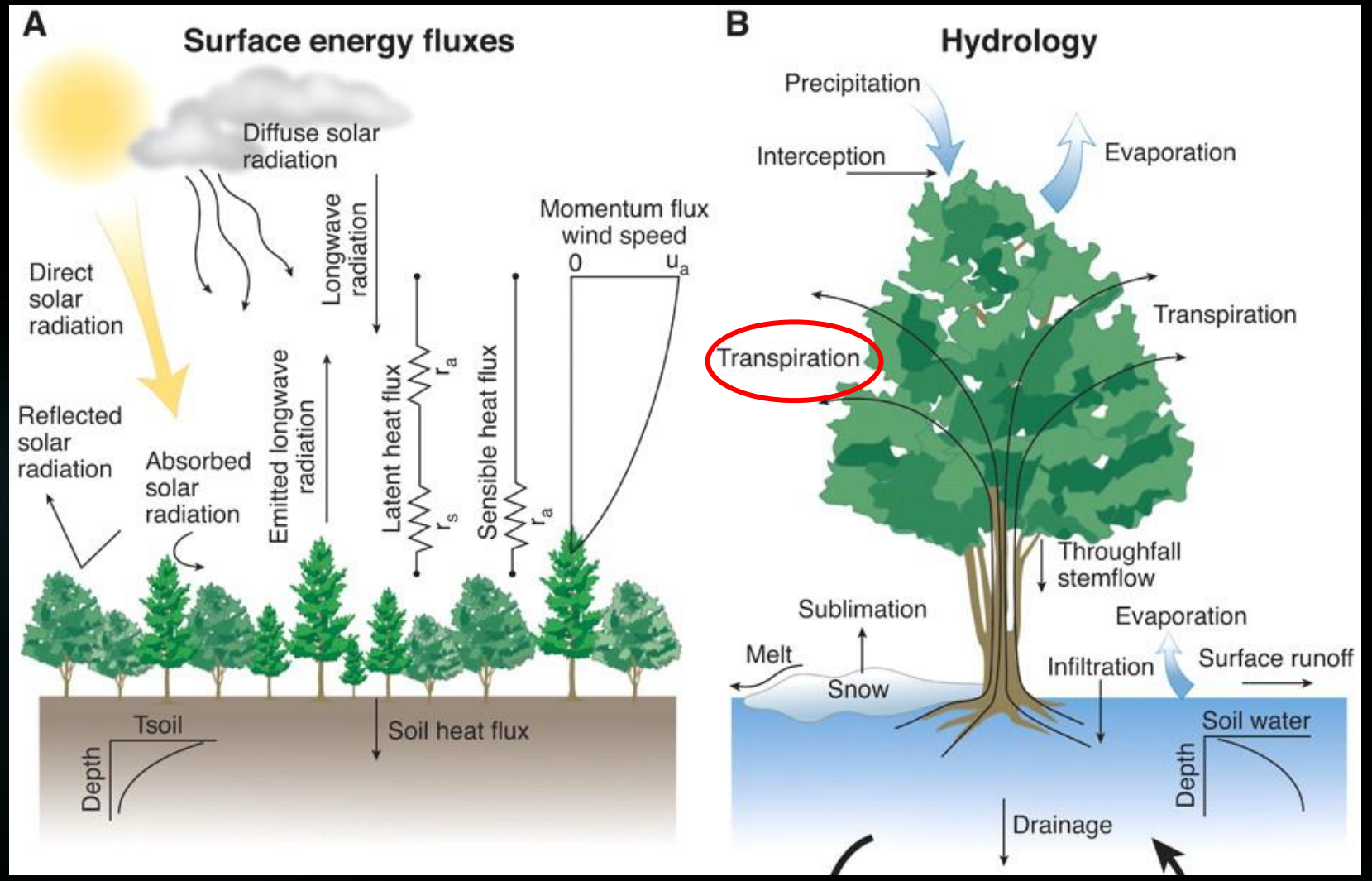
Regionally strong feedbacks between the atmosphere and terrestrial biosphere

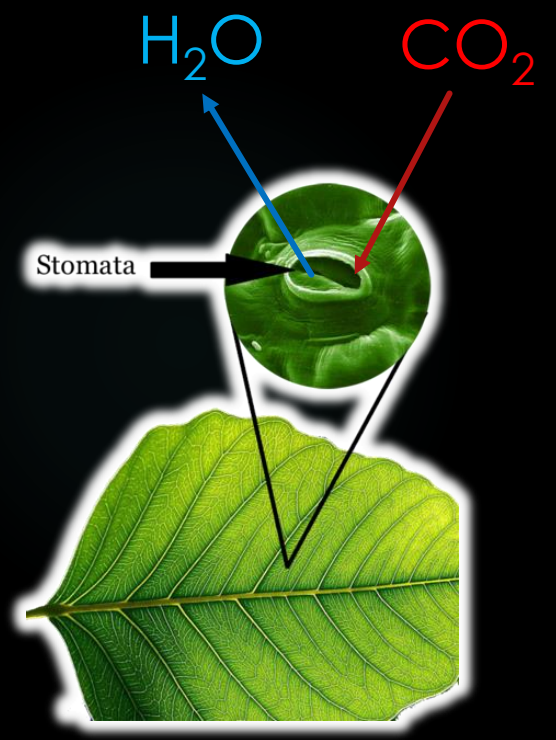
Project Collaborators




Biosphere-atmosphere interactions





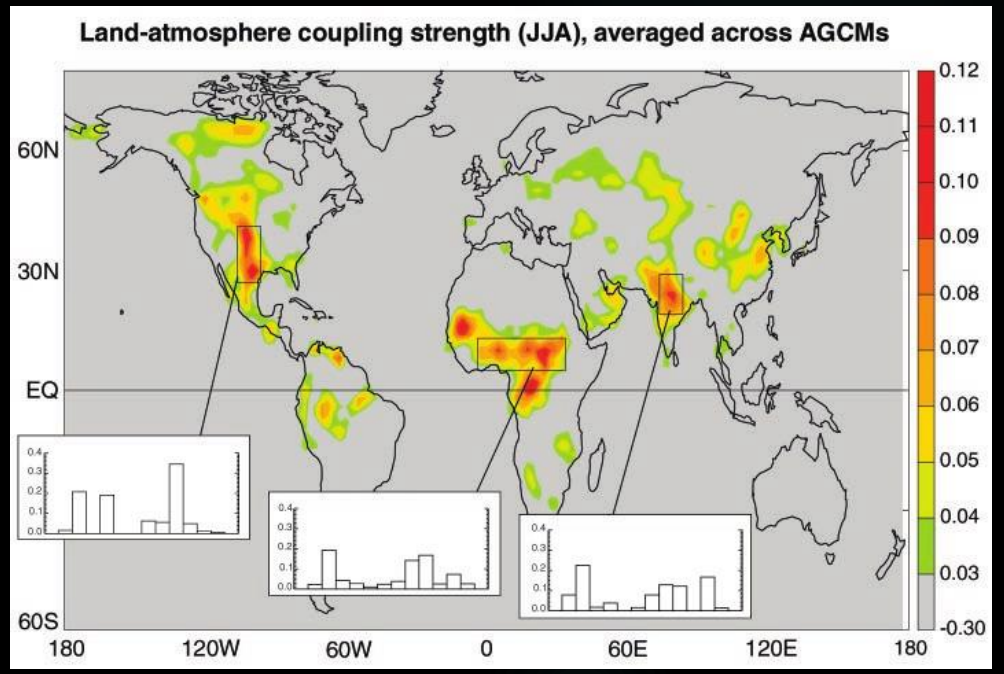
Bonan (2008)

Biosphere-atmosphere interactions

- Modify weather patterns
- Contribute to climate anomaly persistence
- Identify regions susceptible to extremes

Project Research Objectives

- Identify regions of strong biosphere-atmosphere interactions
- Quantify weather and climate variability associated with these feedbacks
- Create benchmark for ESMs
- Evaluate ESMs



Koster et al. (2004)

Methods - datasets

Observational variables (monthly)	Data source
Precipitation	GPCP
Photosynthetic active radiation (PAR)	CERES
Temperature	ERA-INTERIM
Solar Induced Fluorescence (SIF)	GOME-2

- Monthly data
- 2007-2015
- One-degree by one-degree spatial resolution

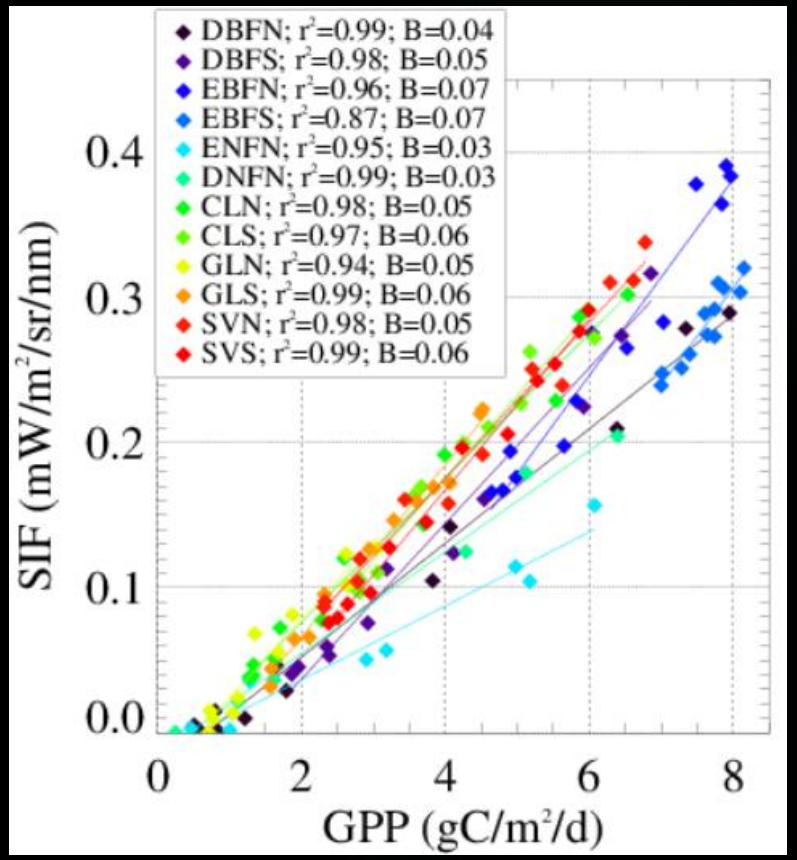
Methods - Solar Induced Fluorescence (SIF)

During photosynthesis a plant absorbs energy through its chlorophyll

- % used for GPP
- % lost as heat
- % re-emitted (SIF)

- Relation between GPP and SIF is ~linear
- It can also be used to infer information about transpiration

$$GPP = wue\ T$$



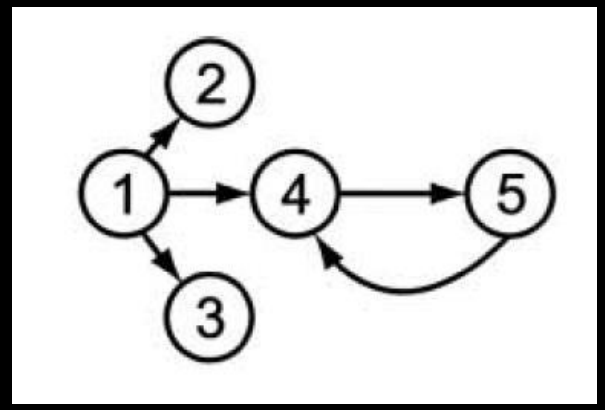
Guanter et al. (2013)

Methods - Conditional Multivariate Granger Causality

Based on Vector Autoregressive (VAR) models

$$\boldsymbol{U}_t = \sum_{k=1}^{p} A_k \cdot \boldsymbol{U}_{t-k} + \boldsymbol{\varepsilon}_t$$

Computes added variance with each variable to define **causality direction and strength**



Seth et al. (2011)

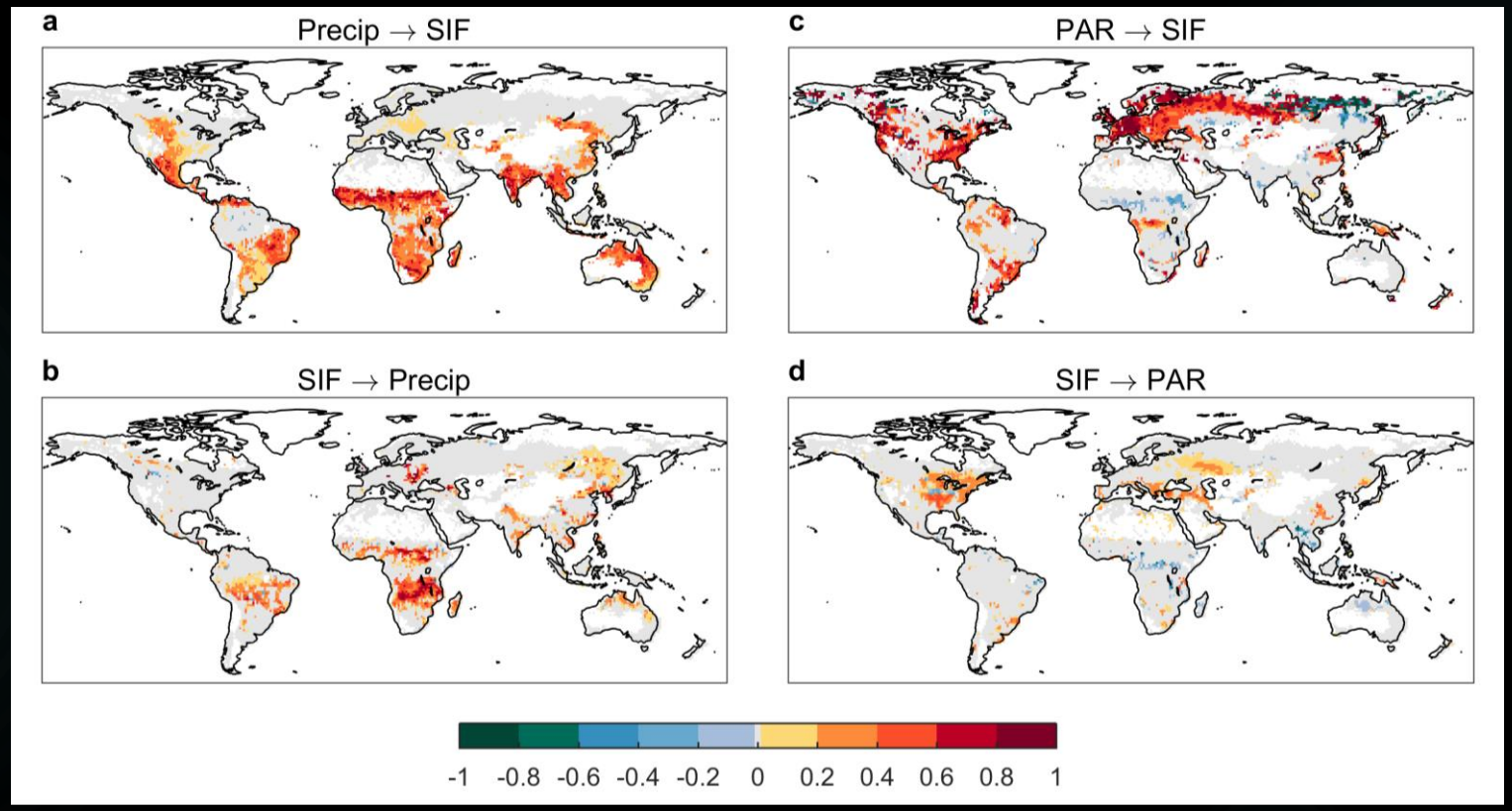
Conditions out joint effects of predictor variables

Results - Observations

- Consider PAR, Precipitation, Temperature and SIF
- Monthly time scale- 1° spatial resolution- remote sensing only (2007-2015)

Atmosphere
↓
Biosphere

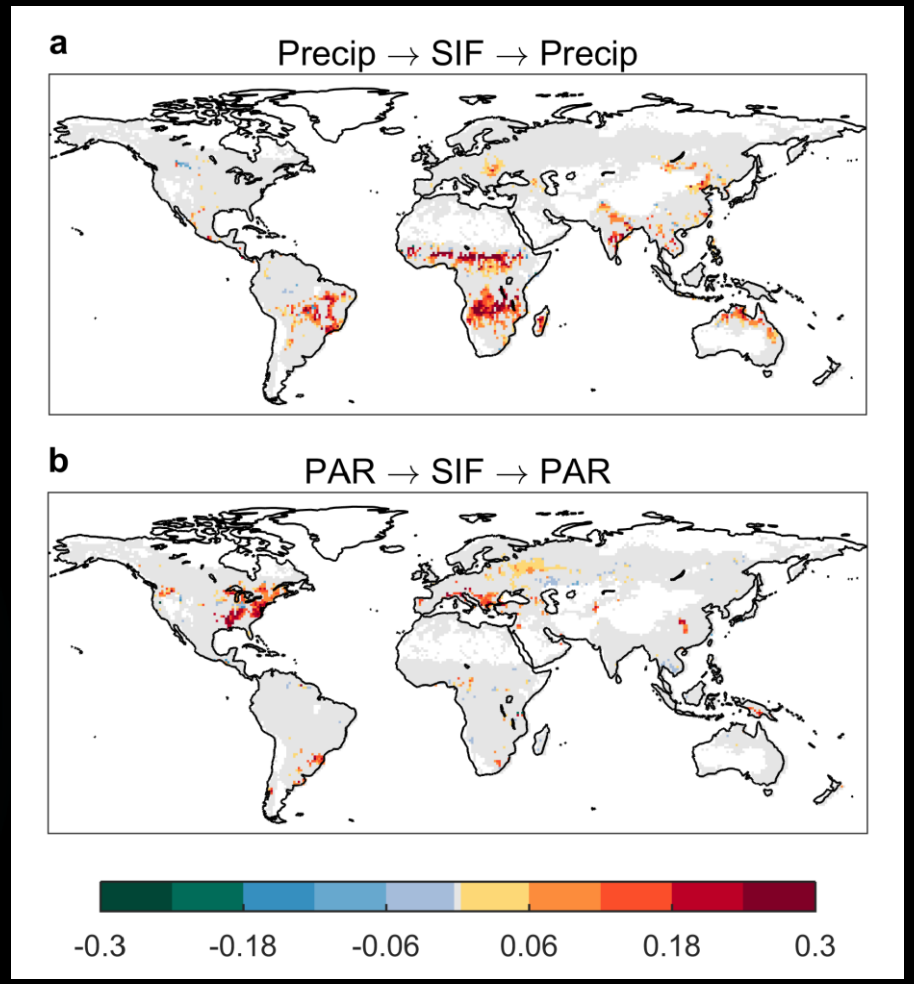
Atmosphere
↑
Biosphere



Fraction of Variance explained

Green, J.K. et al. (2017)

Results - Observations



Our Benchmark!!

Fraction of Variance explained

Green, J.K. et al. (2017)

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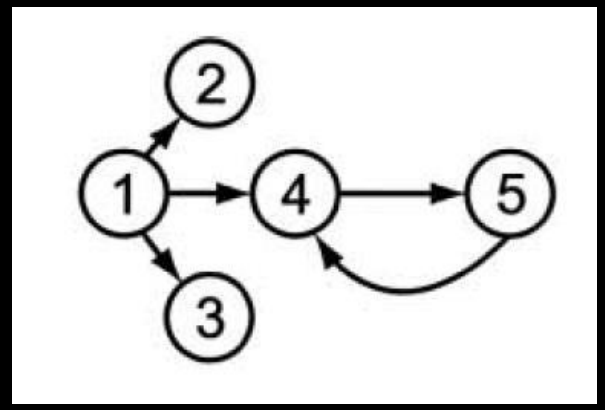

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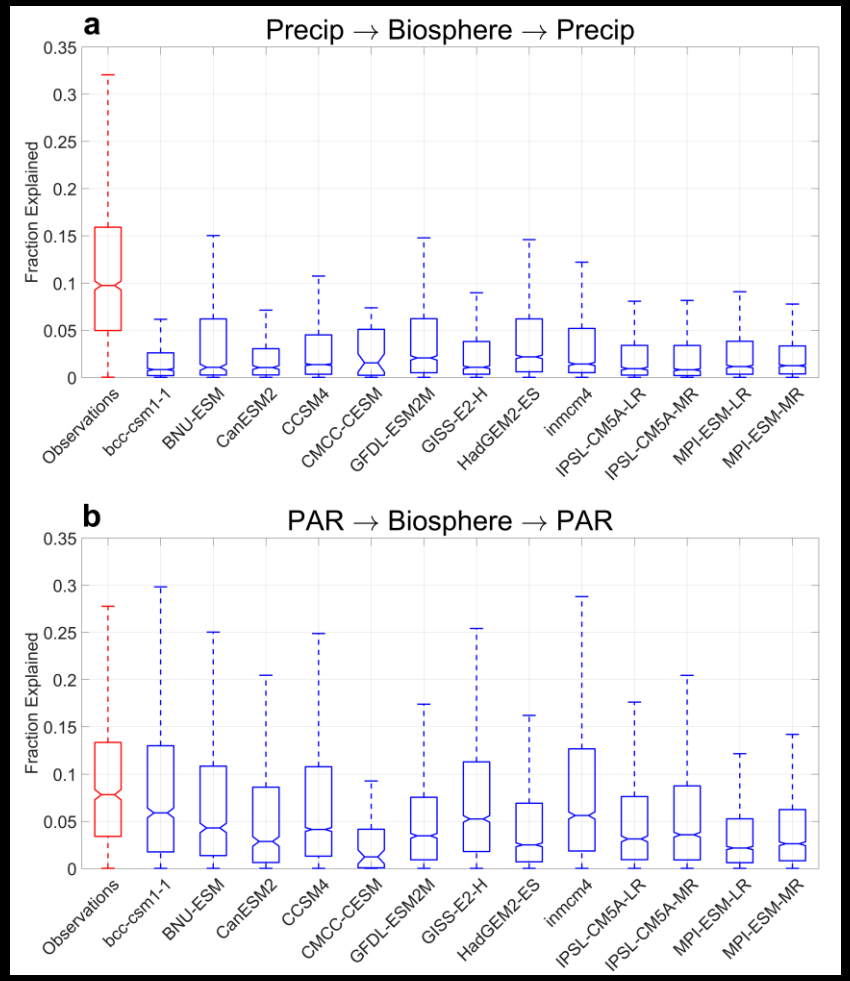
Conditions out joint effects of predictor variables

CMIP5 Models vs. Observations



Models tend to under-estimate biosphere-atmosphere feedbacks due to their representation of water stress

Green, J.K. et al. (2017)

Conclusions

- Biosphere-atmosphere interactions explain up to 30% of variance in radiation and precipitation
  - Semi-arid/monsoonal climates for precipitation
  - Mesic and Mediterranean climates for PAR
- Models underestimate biosphere-atmosphere feedbacks
- High variability between models
- To improve representation of biosphere-atmosphere feedbacks:
  - Photosynthesis
  - Convection, especially over land
  - Water-stress sensitivities

Thank you