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Evaluating JULES and INLAND C fluxes using GEM/LBA data

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Introduction

- **Site level evaluation against GEM and LBA data, targeting biological processes**
  - **experiments to isolate process validation**
- Brazilian C balance evaluation, targeting broader patterns and disturbance
  - Climate gradient analysis across GEM and LCB data
  - Comparison of JULES & INLAND with CARDAMOM model-data fusion C outputs

Climate Science for Service Partnership Brazil

GEM Global Ecosystems Monitoring Network

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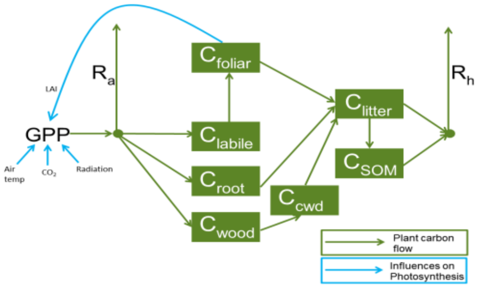
INPE

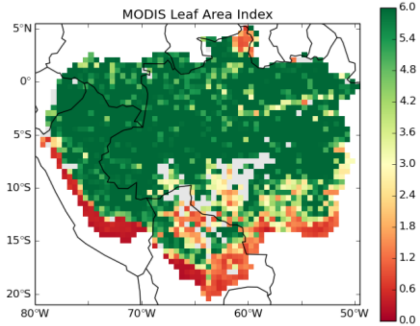
LBA THE LARGE SCALE BIOSPHERE-ATMOSPHERE EXPERIMENT IN AMAZONIA - LBA

Measurements to **E**valuate **M**odelling in **BRA**zilian biomes (MEMBRAne)

http://gem.tropicalforests.ox.ac.uk/

JULES Joint UK Land Environment Simulator





Santarem km67 flux site (LBA)

Global Ecosystem Monitoring (GEM)

Global Ecosystems Monitoring Network

http://gem.tropicalforests.ox.ac.uk/

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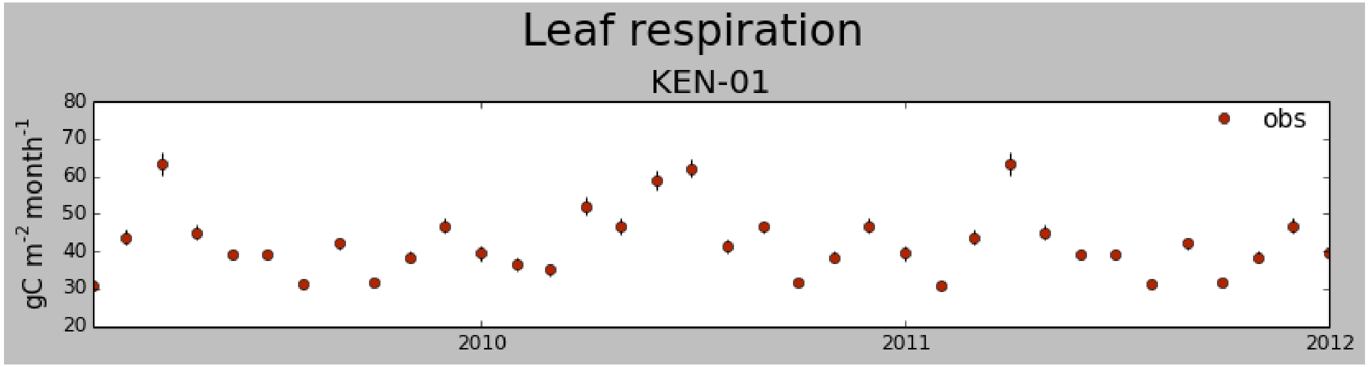
International effort to measure and understand forest ecosystem functions and traits and how these will respond to climate change.



Kenia (Tropical Dry Forest)

UNIVERSITY OF OXFORD

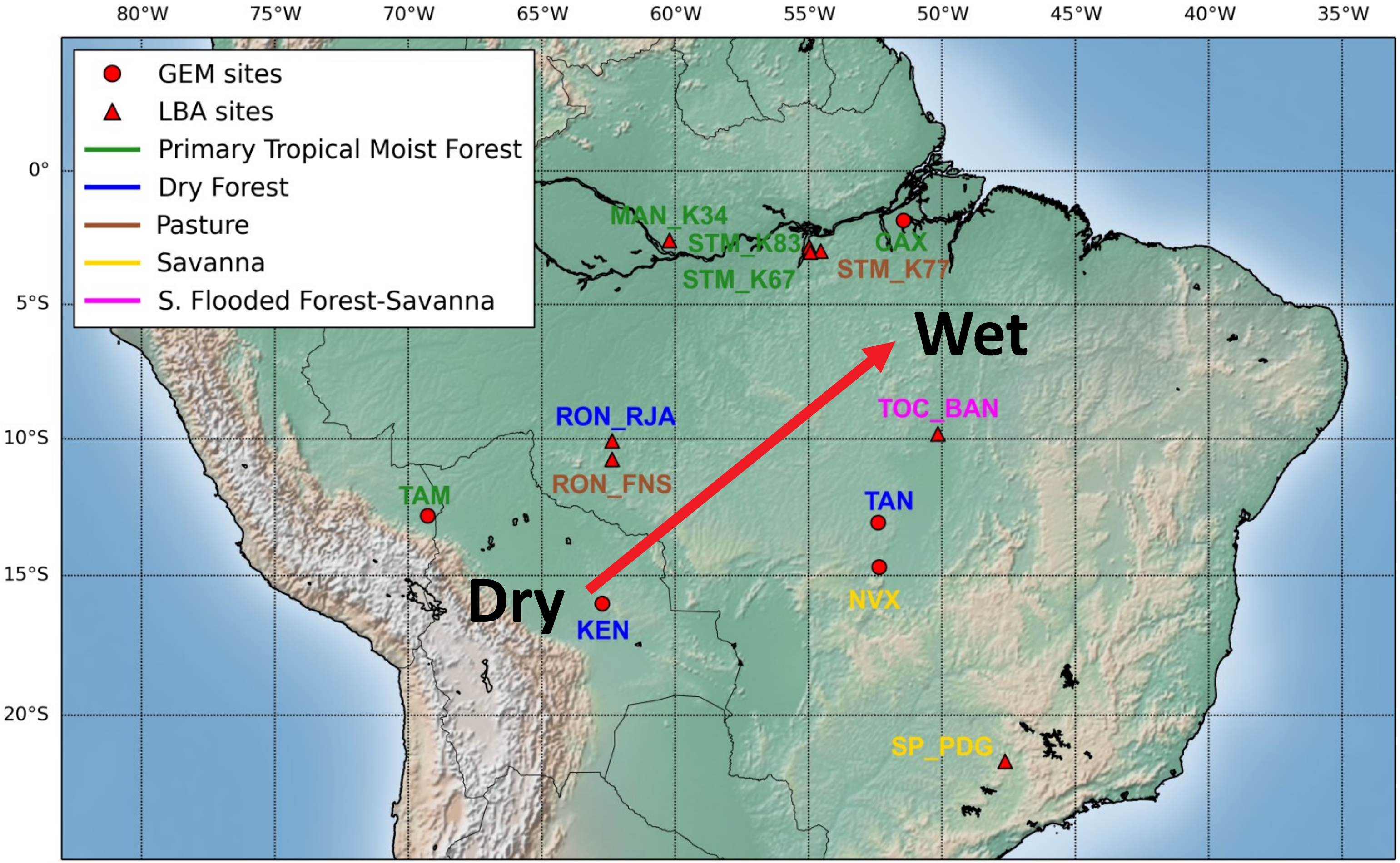
GEM data

- **Plant stocks and dynamics**: Above ground woody biomass and increment, fine root biomass, turnover and production, coarse woody debris (CWD) stocks and turnover (where collected), litter stocks and litterfall.
- **Soil stocks and fluxes:** Quality controlled soil texture, bulk density, soil C:N ratio, soil organic matter content and carbon stocks, soil CO_2 efflux (partitioned into heterotrophic and autotrophic components).
- **Plant fluxes:** Stem CO_2 efflux, CWD CO2 effluxes, leaf gas exchange parameters (photosynthesis, respiration) where collected, specific leaf area, leaf area index (LAI), leaf nitrogen and other nutrients.
- Quality controlled weather data from local meteorological stations, gap-filled, monthly soil moisture time series.

Study sites

Focus is on the major Brazilian biomes (Amazon rainforest, dry forest, and savanna).

- **5 GEM (Global Ecosystem Monitoring) sites.**
- **8 LBA (Large-Scale Biosphere-Atmosphere Experiment in Amazonia) sites.**



Location of GEM/LBA sites used in project.

GEM sites provide comprehensive datasets on C cycling at ecosystem scale across South America.

JULES versus INLAND

- **JULES vn5.2**
  - **J**oint **UK** **L**and **E**nvironment **S**imulator
  - Multi-layer canopy (default is 10) with 4 soil layers (3m depth)
  - 13 surface types
    - ➔ 9 natural PFTs and 4 crop PFTs

- **INLAND vn2.0**
  - **IN**tegrated **LAND** Surface model
  - Derived from IBIS DGVM
  - 2 layer canopy and 6 soil layers (4m depth)
  - 16 surface types
    - ➔ 12 natural PFTs and 4 crop PFTs

Broadly similar PFT types (e.g. tropical broadleaf evergreen, temperate broadleaf evergreen, evergreen shrubs)

Both represent terrestrial surface physical processes, canopy physiology, phenology, vegetation dynamics, terrestrial C balance and water cycle.

Research questions

- Do the LSMs correctly represent the partitioning of NEE into its biological components i.e.\,GPP, NPP, Rh and Ra?

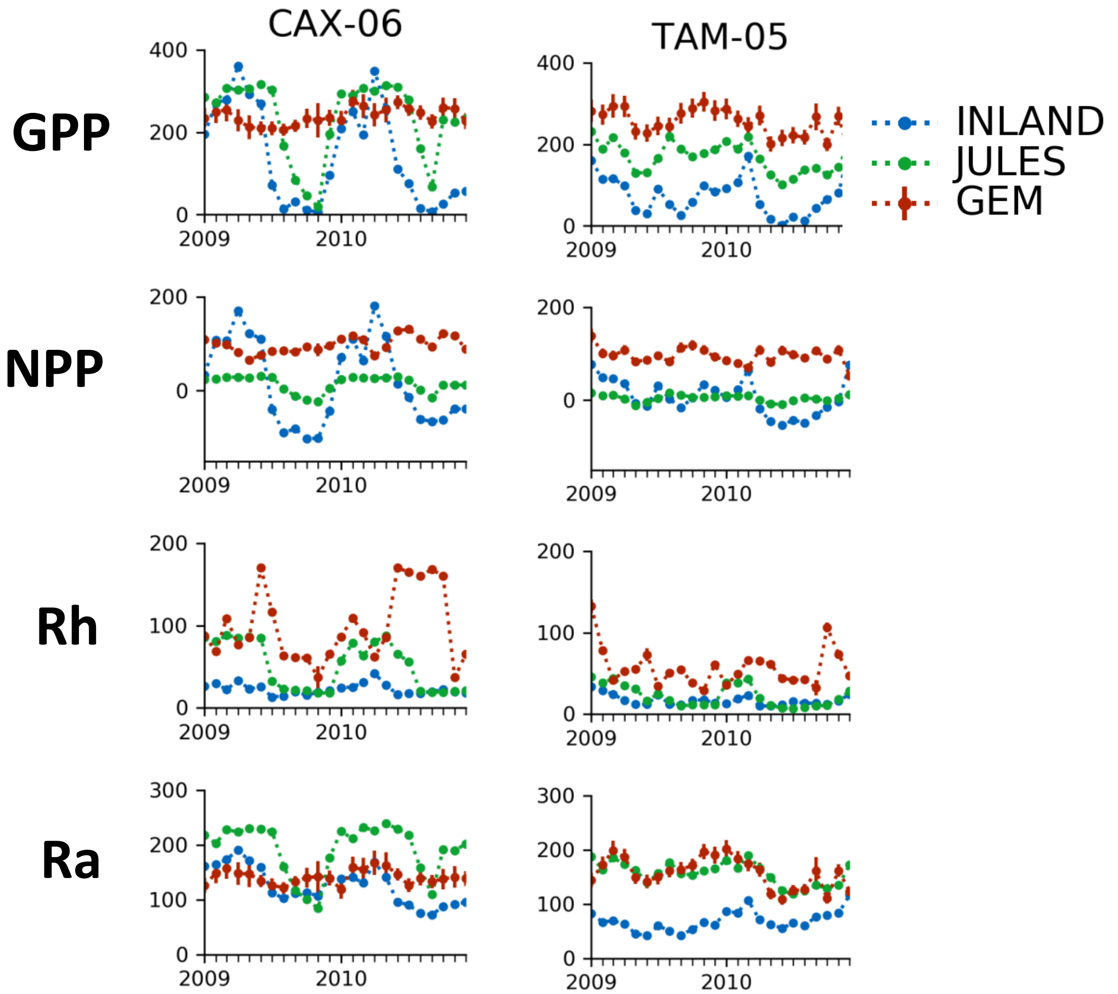
- Do the LSMS represent the sensitivity of C fluxes to environmental drivers correctly?

Do the LSMs correctly represent the partitioning of NEE into its biological components i.e.\,GPP, NPP, Rh and Ra?

- Both models underestimated all fluxes at all sites in comparisons with GEM observations

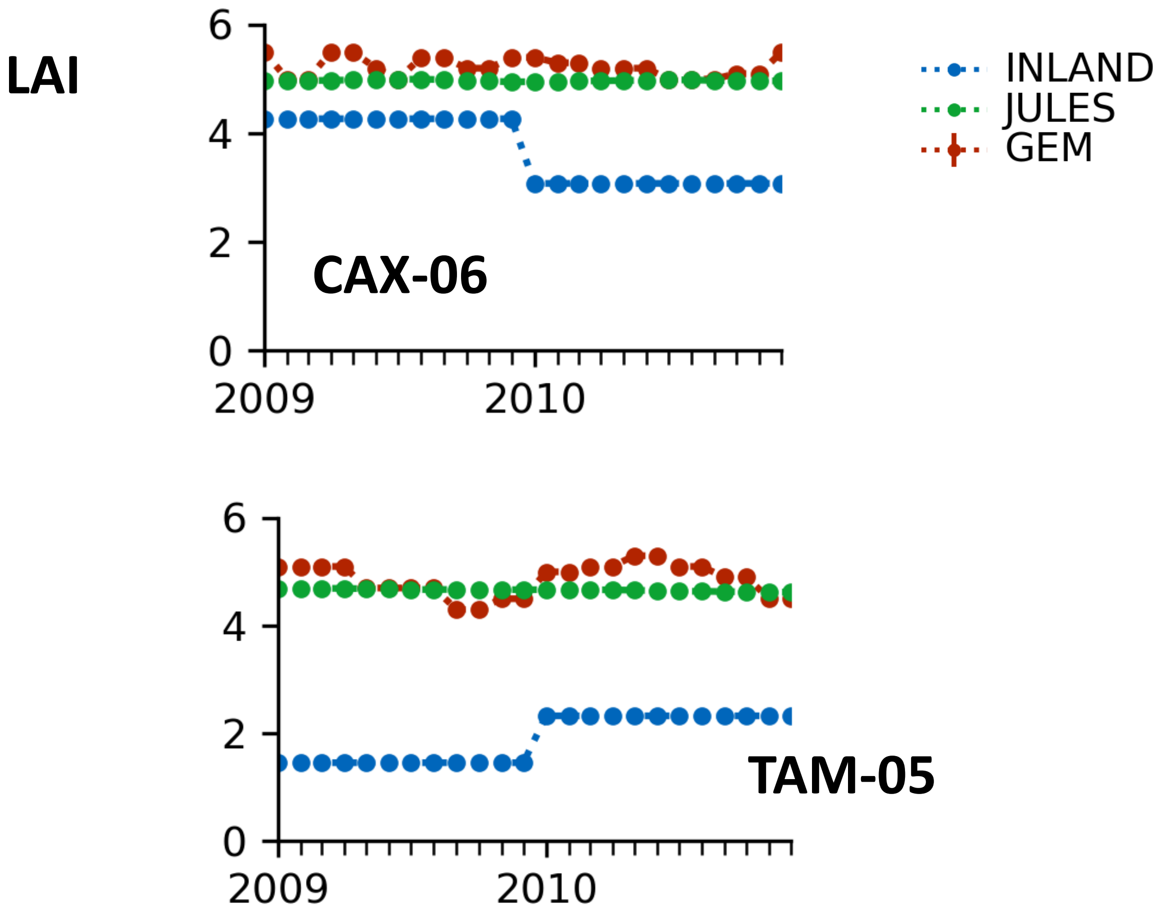
- Underestimation of GPP
  - ➔ JULES by 36% and INLAND by 56% across all sites

- Overall underestimation was greatest for INLAND (on average 38% of magnitude of GEM data), compared to JULES (48% of GEM)



GPP = NPP + Ra; Reco = Rh + Ra

Do the LSMs correctly represent the partitioning of NEE into its biological components i.e.\,GPP, NPP, Rh and Ra?



Strong seasonal cycle of GPP in the models

Likely linked to stomatal closure as modelled seasonality in LAI is relatively minor

GPP = NPP + Ra; Reco = Rh + Ra

Carbon use efficiency (CUE)

At the 5 GEM sites, the estimated CUE varied from 0.25-0.41, with a mean of 0.36

Overall, modelled CUEs were a small fraction (21% for JULES and 29% for INLAND) of the GEM estimates.

INLAND can generate **negative CUE** → NPP < 0 in some months

Year	Model	CAX-04	CAX-06	KEN-02	TAM-05	TAM-06
2009	INLAND	0.1	0.1	-	0.27	0.27
	JULES	0.14	0.06	0.16	0.03	0.04
	GEM	0.26	0.39	0.38	0.38	0.36
2010	INLAND	0.17	0.17	-	-0.11	-0.11
	JULES	0.13	0.07	0.11	0.02	0.03
	GEM	0.25	0.43	0.38	0.38	0.4
$\overline{CUE}$	**INLAND**	**0.13**	**0.13**	**-**	**0.08**	**0.08**
	JULES	**0.13**	**0.06**	**0.13**	**0.02**	**0.03**
	GEM	**0.25**	**0.41**	**0.38**	**0.38**	**0.38**

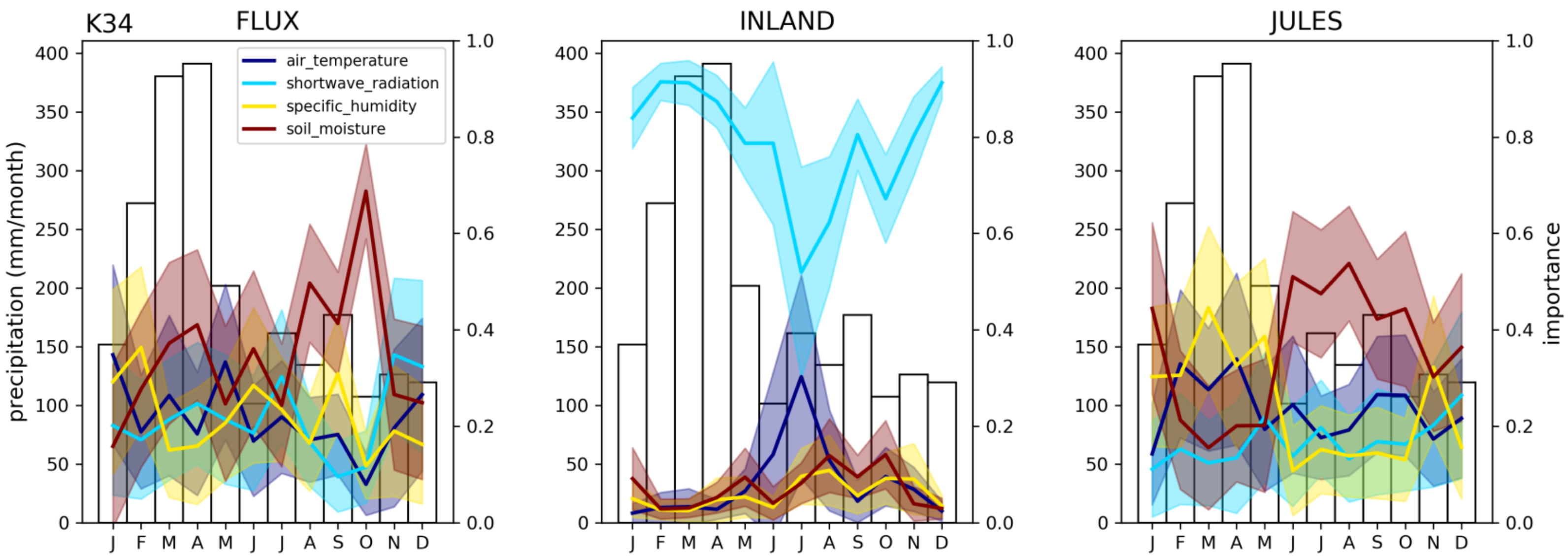
CUE = NPP/GPP

Do the LSMs represent the sensitivity of C fluxes to environmental drivers correctly?

Random Forest machine learning algorithm used to identify environmental controls on variability of GPP, Reco and NEE.

NEE

Calculates the relative importance of environmental drivers



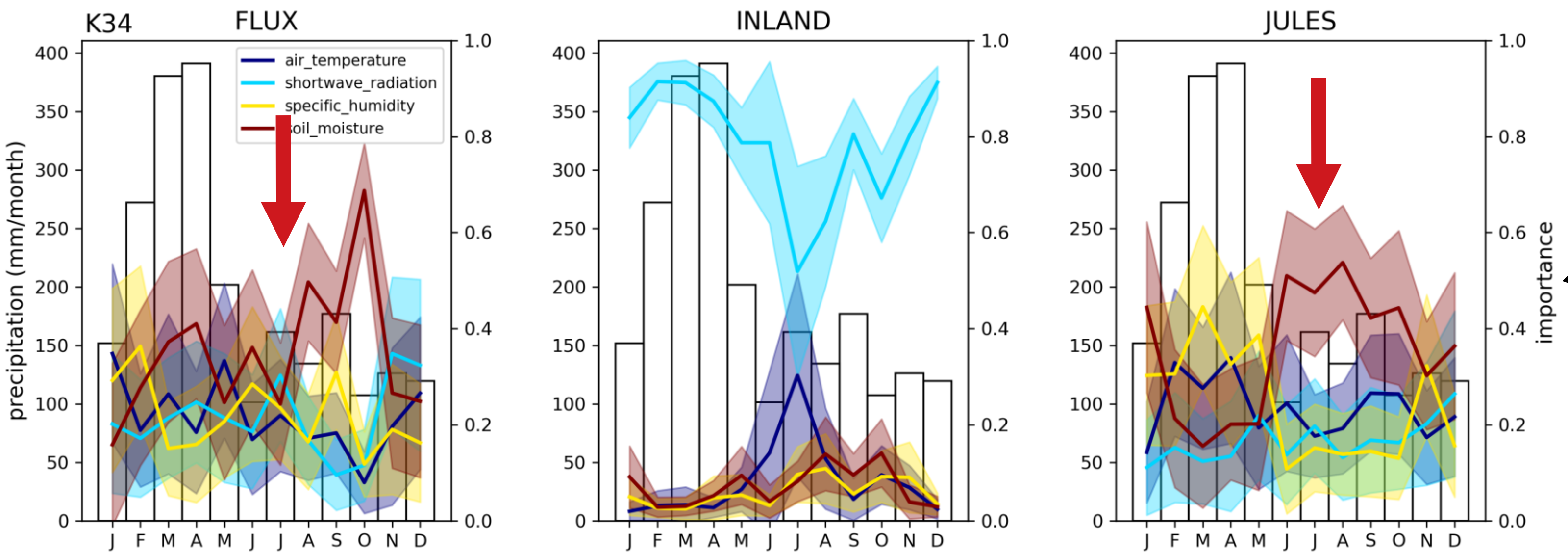
Primary Tropical Moist Forest

Do the LSMs represent the sensitivity of C fluxes to environmental drivers correctly?

Random Forest machine learning algorithm used to identify environmental controls on variability of GPP, Reco and NEE.

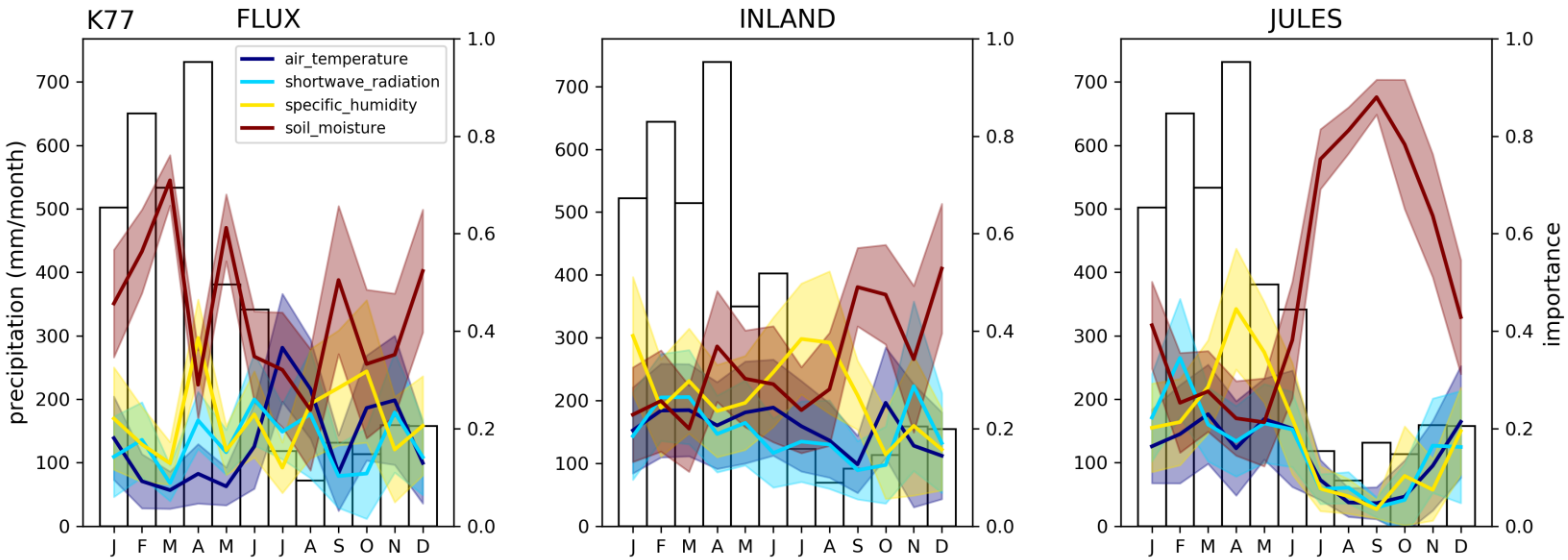
NEE

Strongest sensitivity of FLUX and JULES C fluxes were due to variation in **soil moisture** during low rainfall months.



Primary Tropical Moist Forest

NEE



Pasture

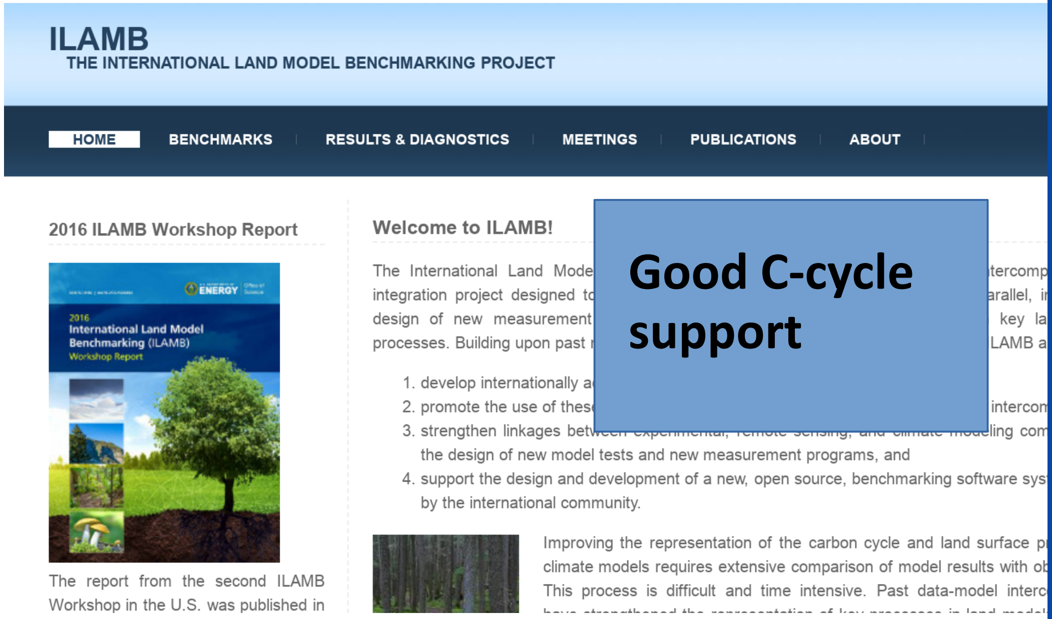
	Site	FLUX				INLAND				JULES			
		tair	sw	qair	soil	tair	sw	qair	soil	tair	sw	qair	soil
NEE	BAN	1.82	4.53	2.04	3.59	2.93	5.15	1.68	2.21	1.62	0.81	1.68	7.86
	K34	2.62	2.57	2.68	4.12	0.94	9.46	0.71	0.87	2.82	1.99	2.92	4.25
	K83	2.66	4.15	2.44	2.73	1.87	7.13	1.22	1.76	3.15	1.07	1.89	5.87
	RJA	2.72	2.6	2.7	4.02	1.61	6.08	2.55	1.74	2.38	2.53	2.32	4.75

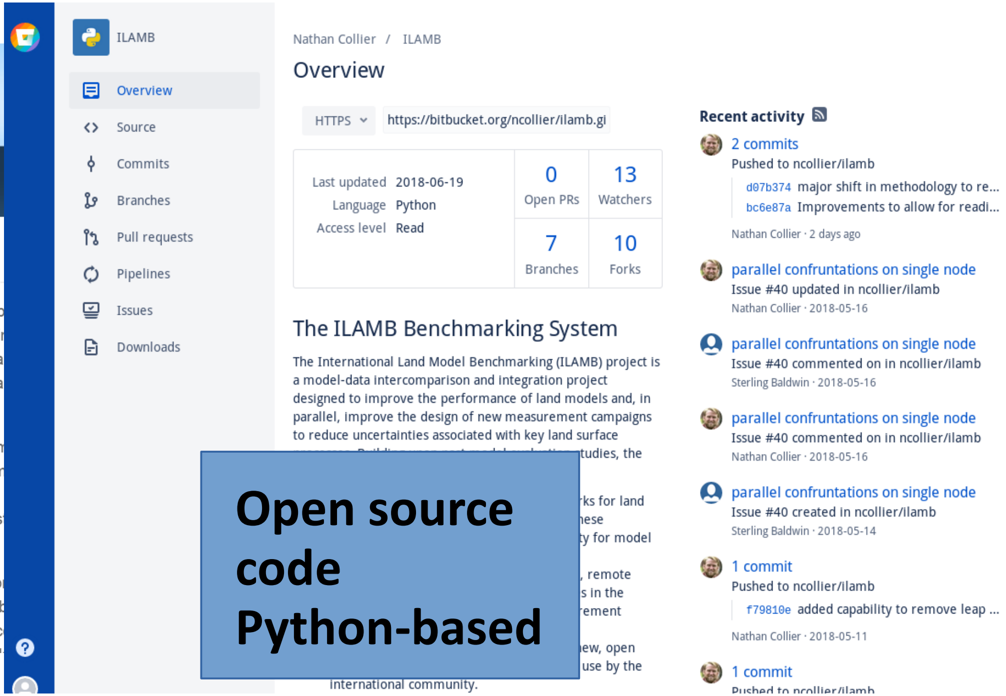
INLAND has strong sensitivity to radiation during the wet season.

Green is the most important, then red, blue, with cyan being the least important.

Model Evaluation Frameworks - ILAMB

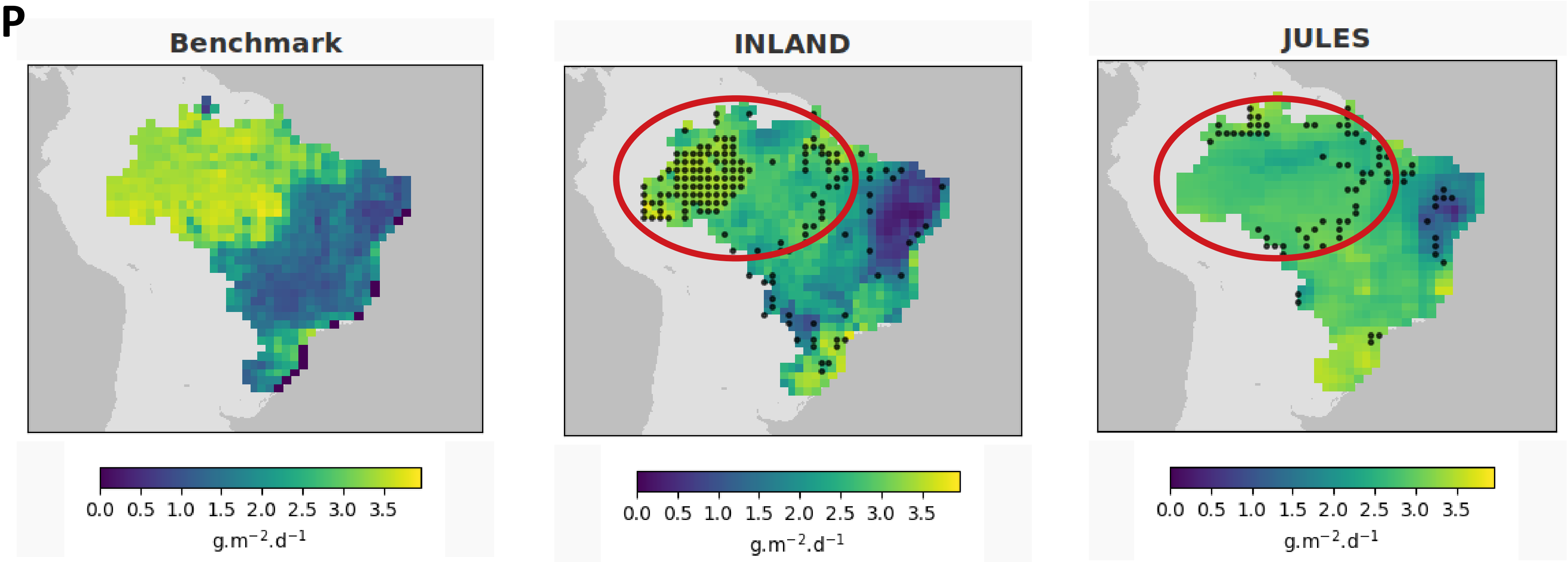
- The **International Land Model Benchmarking (ILAMB)** project is a model-data intercomparison and integration project and software package designed to improve the performance of land models. (Oak Ridge National Lab, US)





Model Evaluation Frameworks - ILAMB

NPP



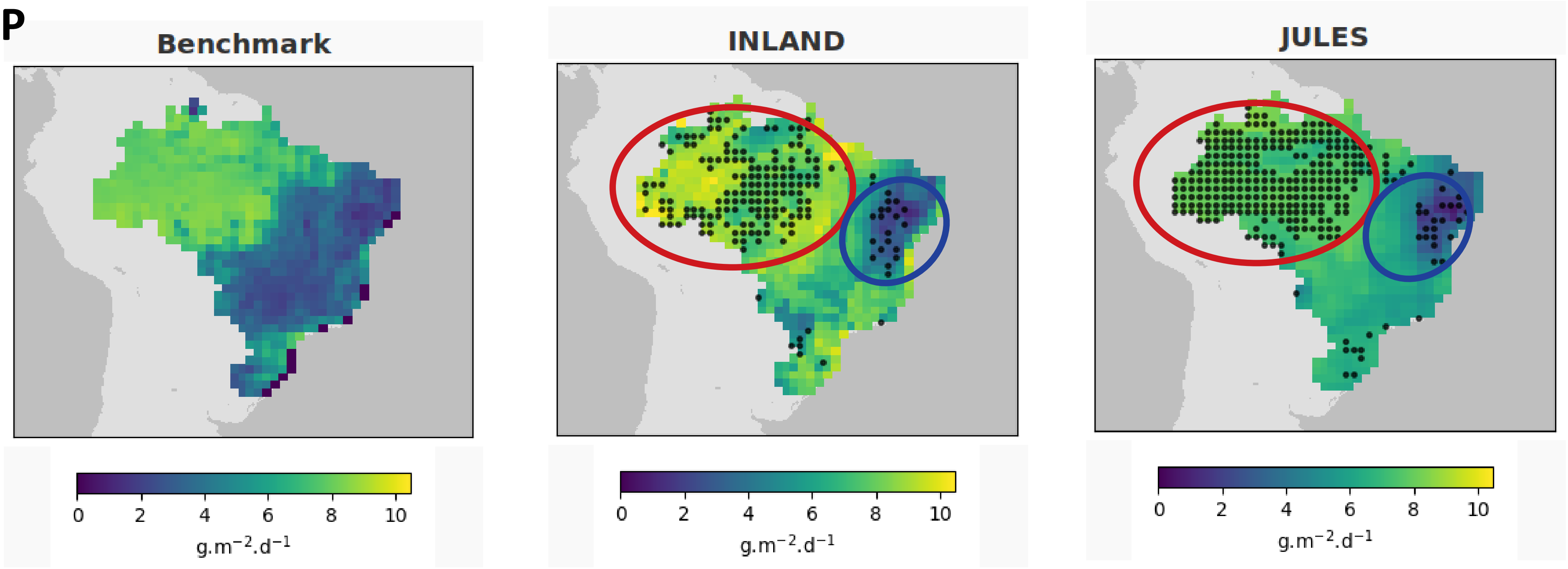
- **Benchmark is CARDAMOM**
- **Stippling → models fall within +/- 10% of benchmark**

INLAND NPP closer to benchmark in **Amazon state**

Model Evaluation Frameworks - ILAMB

Both models do well at capturing GPP in **Amazon state** and **Caatinga** dry forest

GPP



Summary

- The LSMs used in this study do not well represent the partitioning of NEE into its individual components at the GEM sites
- The underestimation of GPP has knock-on effects for the simulation of other, downstream components of the C cycle
    - Driven by strong seasonal cycle in the models
    - Likely linked to stomatal closure as modelled seasonality in LAI is relatively minor
- Sensitivity of C fluxes to environmental drivers
    - Soil moisture (JULES)
    - Downward shortwave radiation (INLAND)