



THE UNIVERSITY
of EDINBURGH

Evaluating JULES and INLAND C fluxes using GEM/LBA data

Darren Slevin, Mat Williams, Tristan Williams
University of Edinburgh

Celso von Randow, Manoel Cardoso, Aline Anderson de Castro
Brazilian Institute for Space Research (INPE)

Yadvinder Malhi + GEM team
University of Oxford

+ Karina Williams, Anna Harper

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

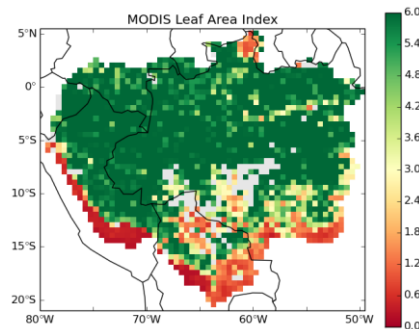
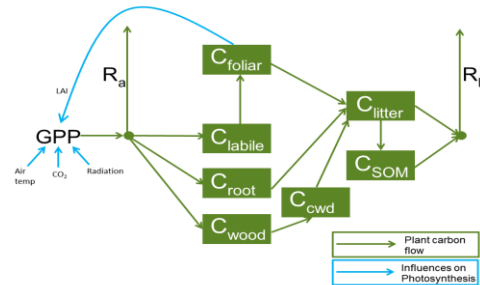


Measurements to Evaluate Modelling in BRAzilian biomes (MEMBRAnE)



Santarem km67 flux site (LBA)

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



Global Ecosystem Monitoring (GEM)

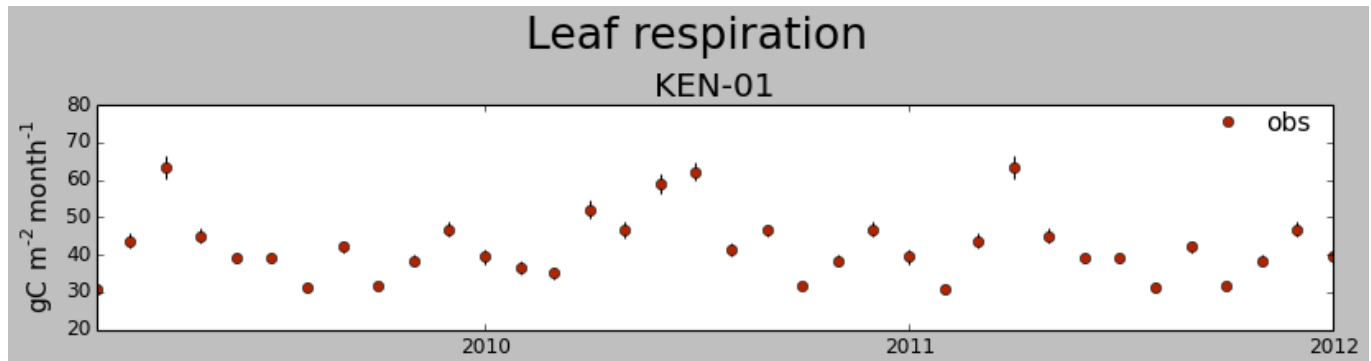


<http://gem.tropicalforests.ox.ac.uk/>



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

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



Kenia (Tropical Dry Forest)





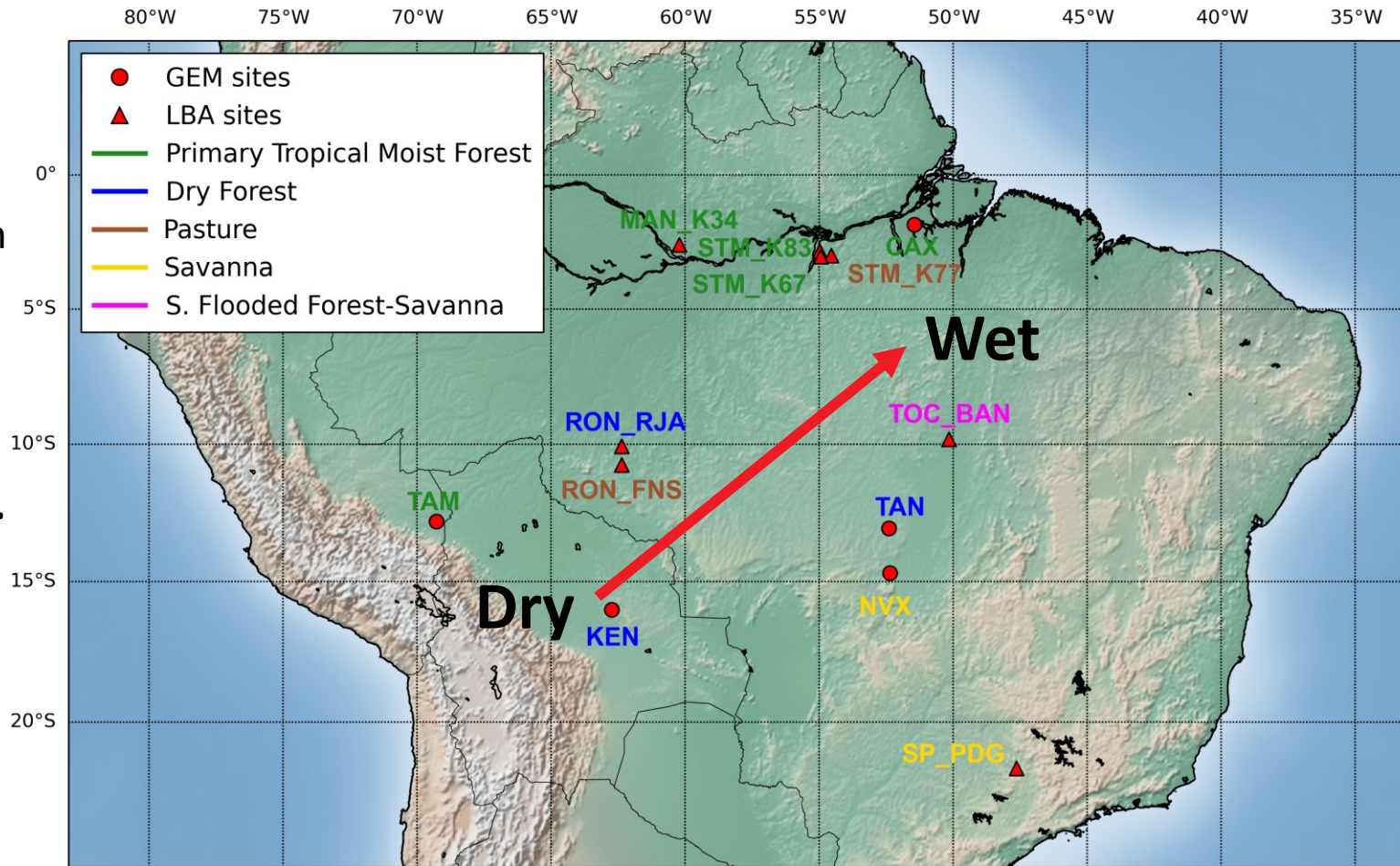
GEM data

- **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 CO₂ efflux (partitioned into heterotrophic and autotrophic components).
- **Plant fluxes:** Stem CO₂ 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**

- Joint **UK Land Environment Simulator**
- 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**

- **INtegrated 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.

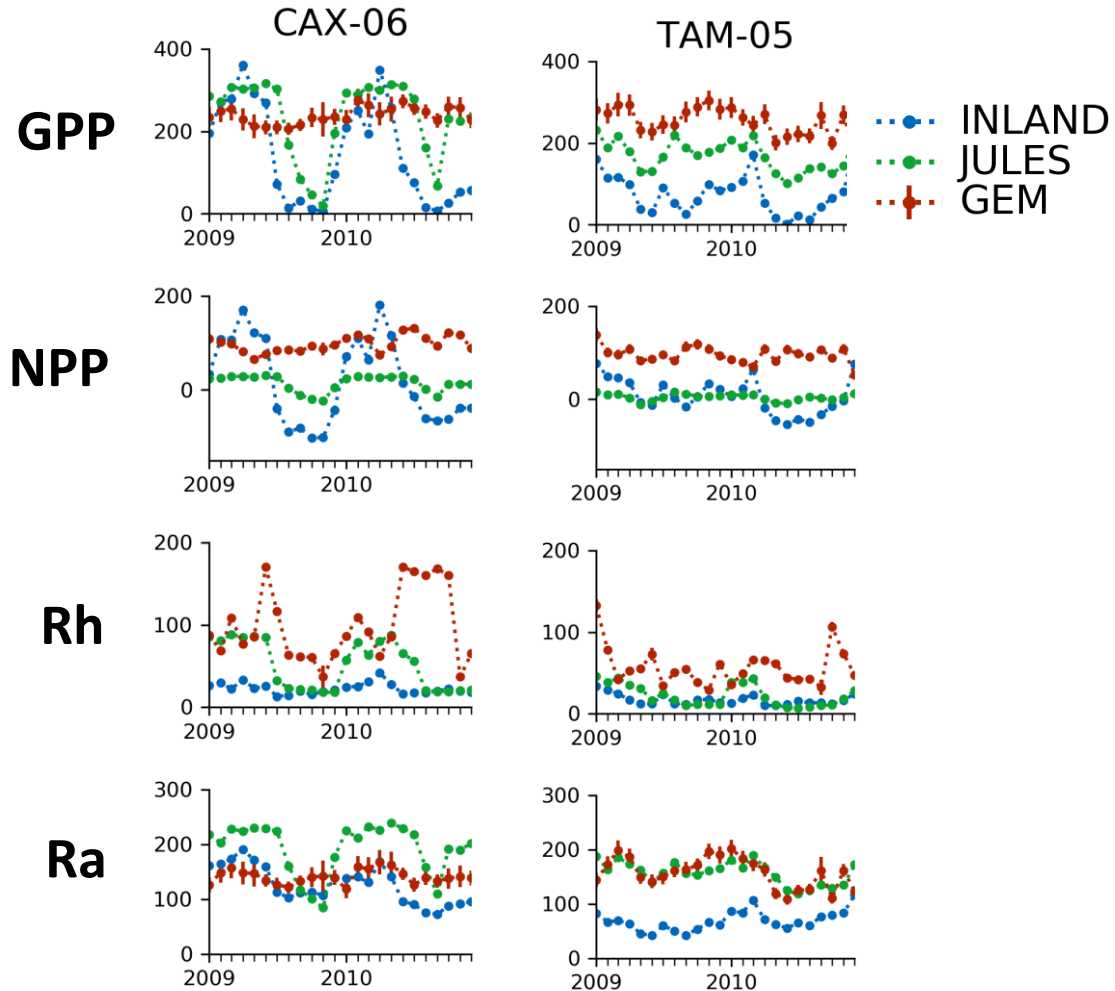
Research questions

- Do the LSMs correctly represent the partitioning of NEE into its biological components i.e. GPP , NPP , R_h and R_a ?
- 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. \backslash , 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)

$$\text{GPP} = \text{NPP} + \text{Ra}; \text{Reco} = \text{Rh} + \text{Ra}$$

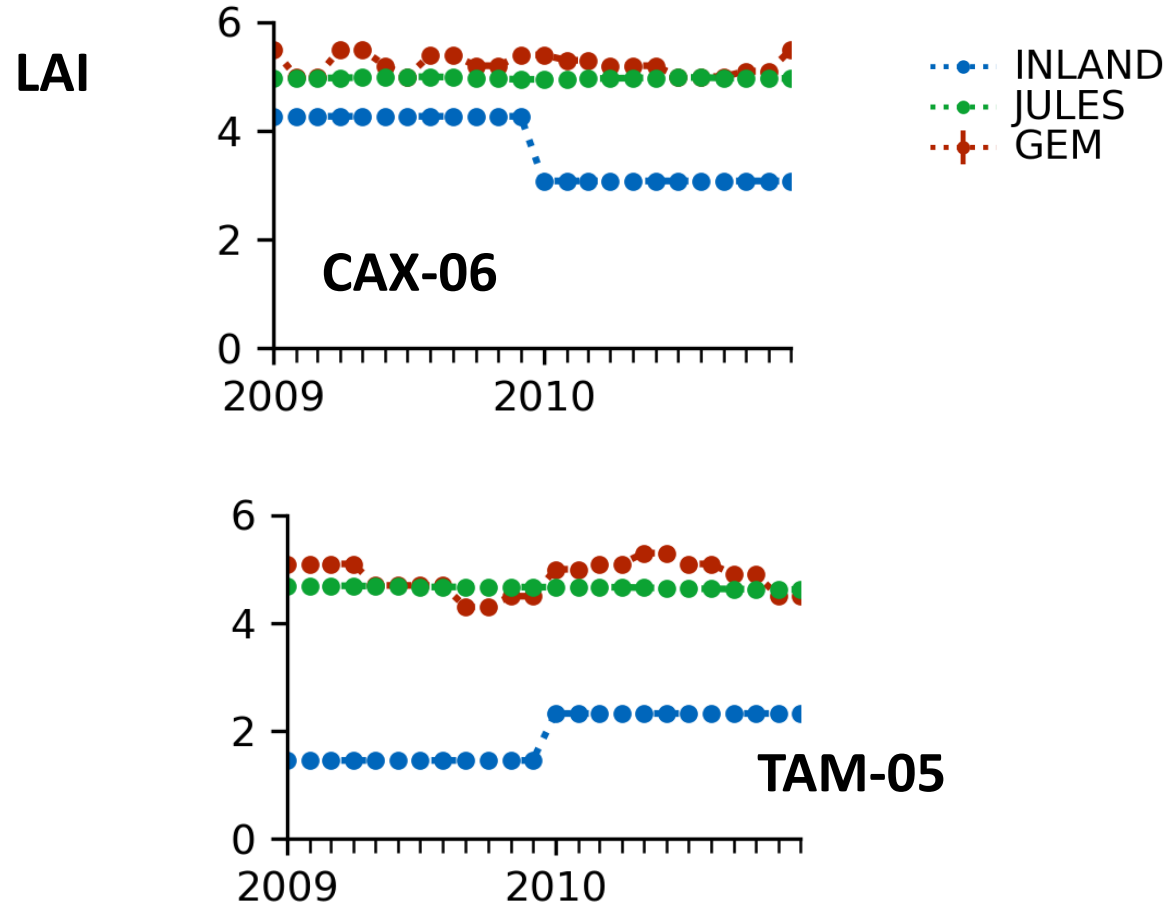


Do the LSMs correctly represent the partitioning of NEE into its biological components i.e. ρ , GPP, NPP, Rh and Ra?

Strong seasonal cycle of GPP in the models

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

$$\text{GPP} = \text{NPP} + \text{Ra}; \text{Reco} = \text{Rh} + \text{Ra}$$



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
$\overline{\text{CUE}}$	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

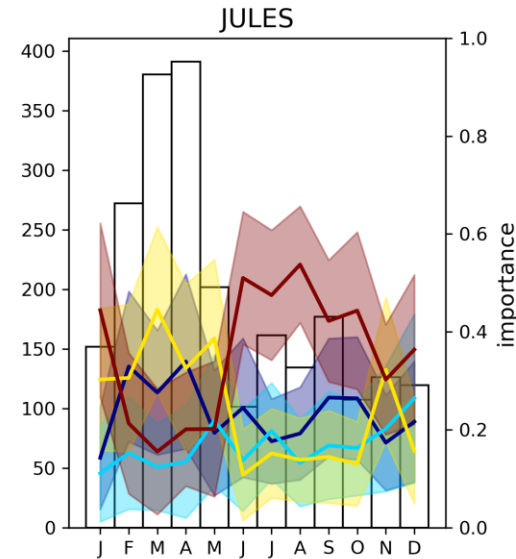
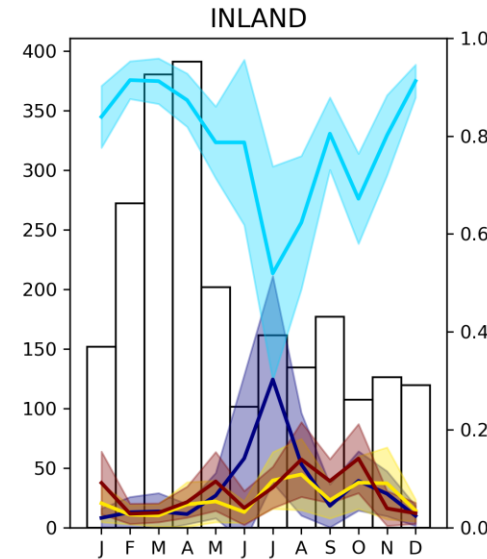
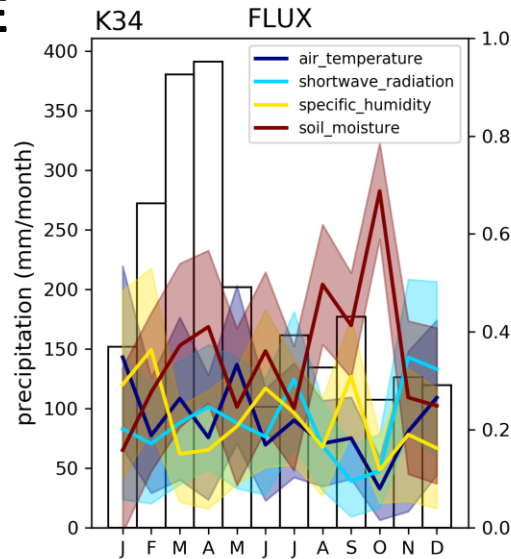
$$\text{CUE} = \text{NPP}/\text{GPP}$$

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



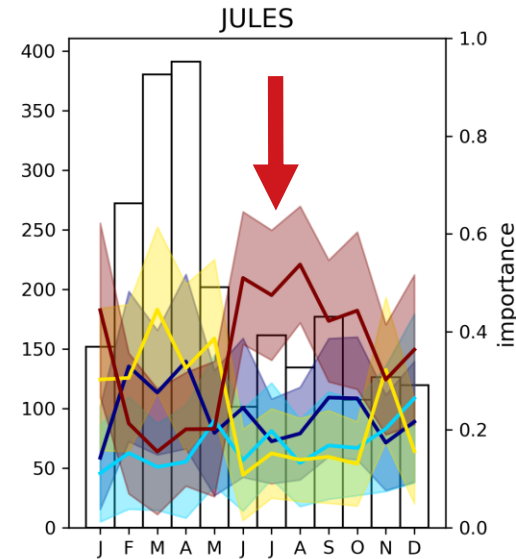
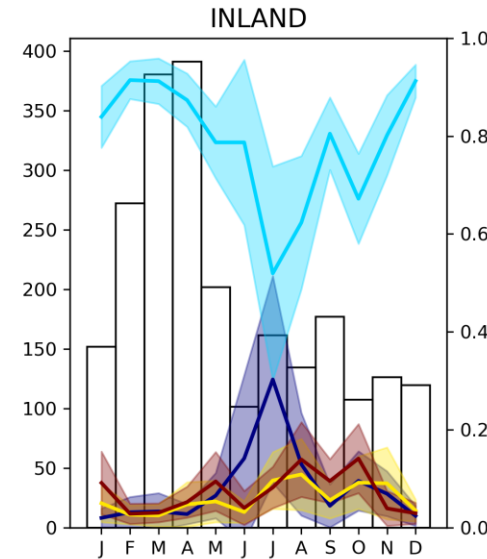
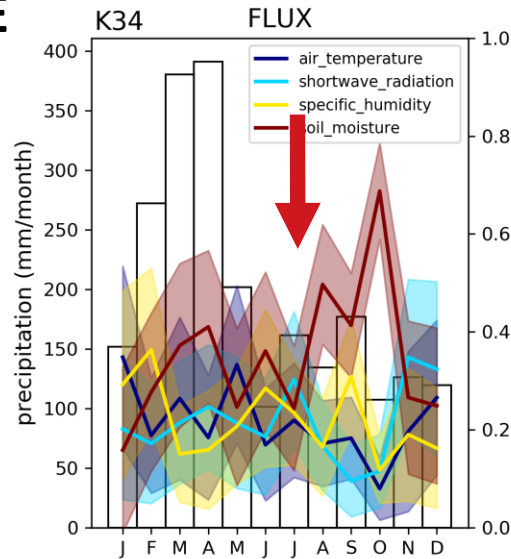
Primary Tropical Moist Forest

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.

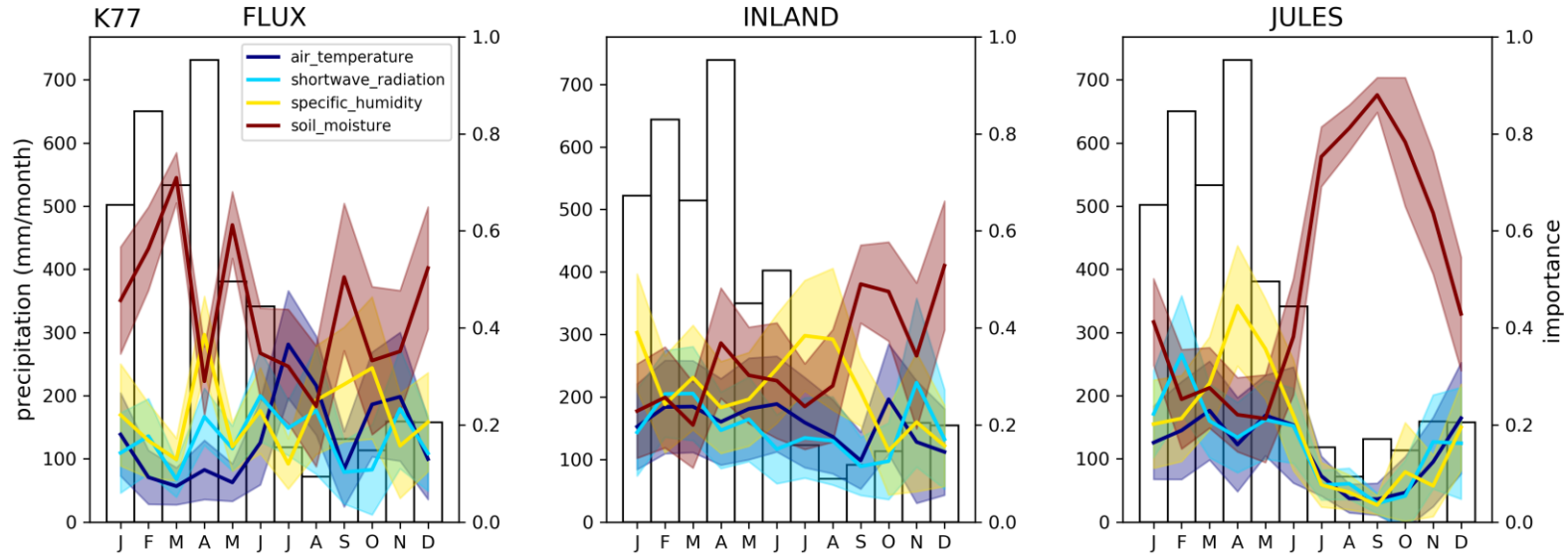
NEE

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

	FLUX				INLAND				JULES				
	Site	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)

The image shows a composite of two screenshots. On the left is the ILAMB website, and on the right is the GitHub repository page for ILAMB.

ILAMB Website:

- Header: ILAMB THE INTERNATIONAL LAND MODEL BENCHMARKING PROJECT
- Navigation: HOME, BENCHMARKS, RESULTS & DIAGNOSTICS, MEETINGS, PUBLICATIONS, ABOUT
- Section: 2016 ILAMB Workshop Report
- Image: 2016 International Land Model Benchmarking (ILAMB) Workshop Report cover
- Text: The report from the second ILAMB Workshop in the U.S. was published in...
- Section: Welcome to ILAMB!
- Text: The International Land Model Benchmarking (ILAMB) project is a model-data intercomparison and integration project designed to improve the performance of land models and, in parallel, improve the design of new measurement campaigns to reduce uncertainties associated with key land surface processes. Building upon past ILAMB activities, the project will:

 1. develop internationally agreed upon protocols for model intercomparison
 2. promote the use of these protocols by the international community
 3. strengthen linkages between experimental, remote sensing, and climate modeling communities to improve the design of new model tests and new measurement programs, and
 4. support the design and development of a new, open source, benchmarking software system by the international community.

- Image: A forest landscape.
- Text: Improving the representation of the carbon cycle and land surface processes in climate models requires extensive comparison of model results with observations. This process is difficult and time intensive. Past data-model intercomparison studies have strengthened the representation of key processes in land models.

GitHub Repository:

- Repository: Nathan Collier / ILAMB
- Overview
- URL: <https://bitbucket.org/ncollier/ilamb.git>
- Statistics:

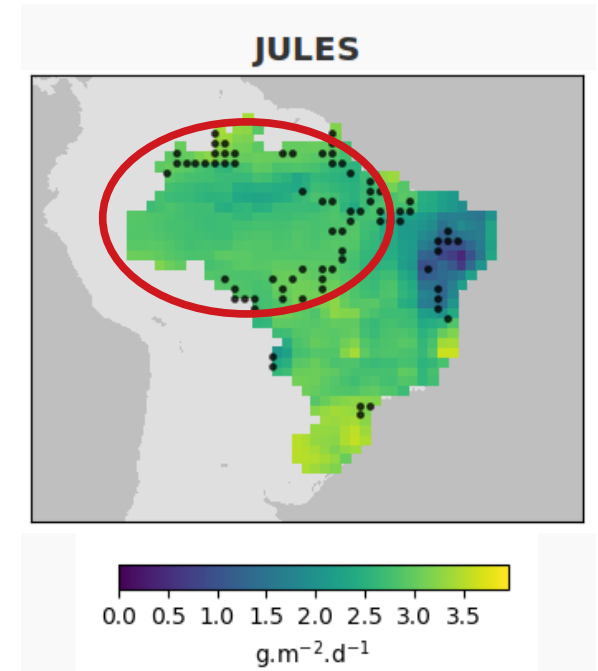
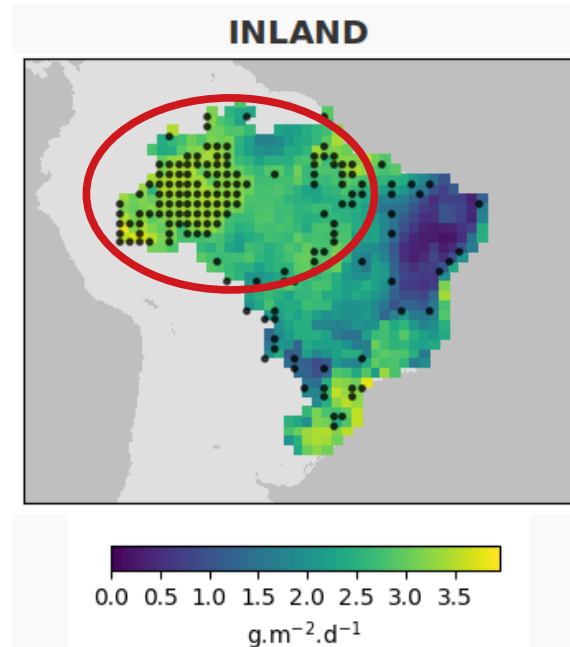
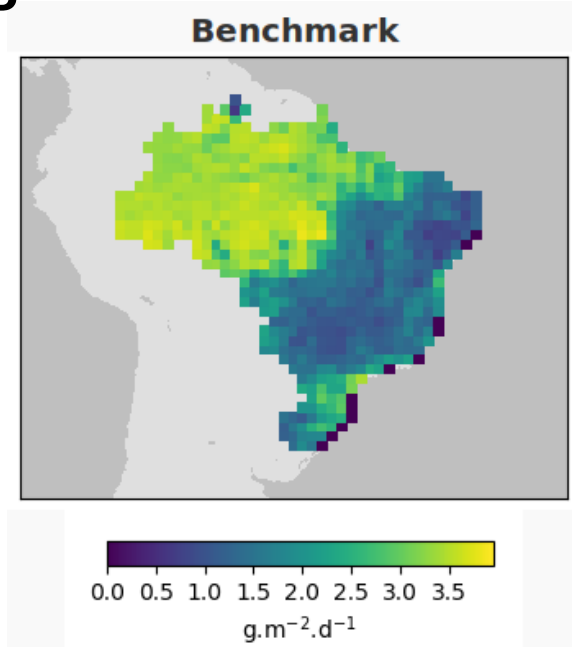
Last updated	2018-06-19	0	13
Language	Python	Open PRs	Watchers
Access level	Read	7	10
		Branches	Forks
- Recent activity:
 - 2 commits
 - Pushed to ncollier/ilamb
 - d97b374 major shift in methodology to re...
 - bc6e87a Improvements to allow for readi...
 - Nathan Collier · 2 days ago
 - parallel confruntations on single node
 - Issue #40 updated in ncollier/ilamb
 - Nathan Collier · 2018-05-16
 - parallel confruntations on single node
 - Issue #40 commented on in ncollier/ilamb
 - Sterling Baldwin · 2018-05-16
 - parallel confruntations on single node
 - Issue #40 commented on in ncollier/ilamb
 - Nathan Collier · 2018-05-16
 - parallel confruntations on single node
 - Issue #40 created in ncollier/ilamb
 - Sterling Baldwin · 2018-05-14
 - 1 commit
 - Pushed to ncollier/ilamb
 - f79810e added capability to remove leap ...
 - Nathan Collier · 2018-05-11
 - 1 commit
 - Pushed to ncollier/ilamb

Good C-cycle support

Open source code Python-based

Model Evaluation Frameworks - ILAMB

NPP



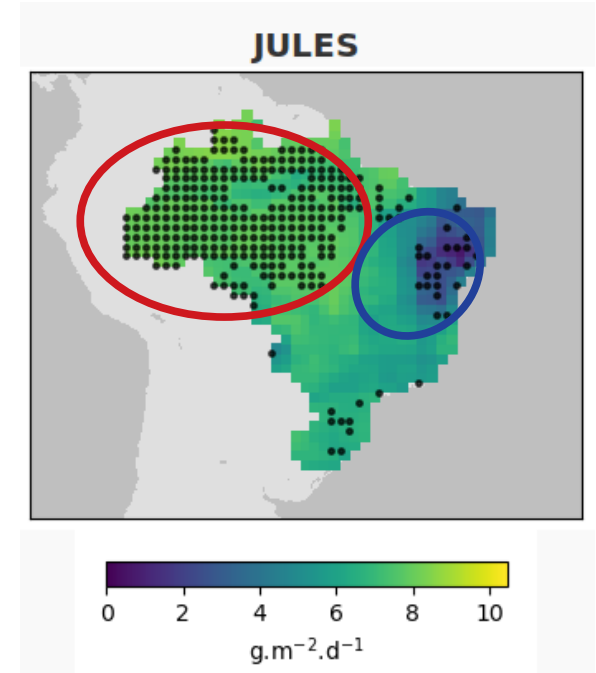
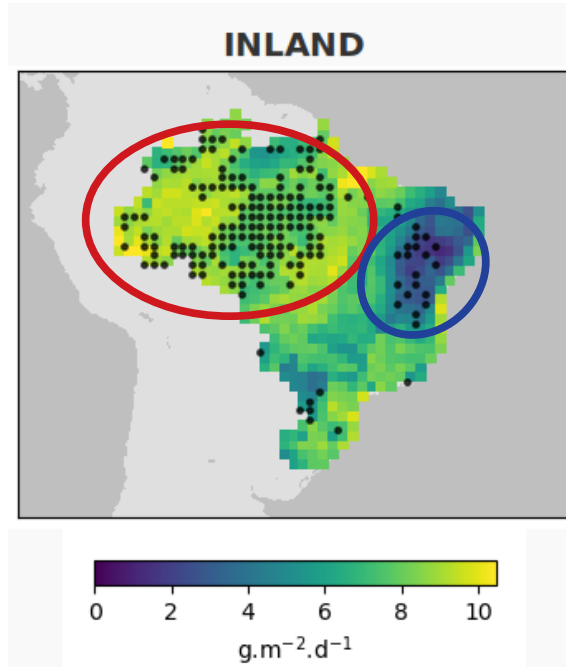
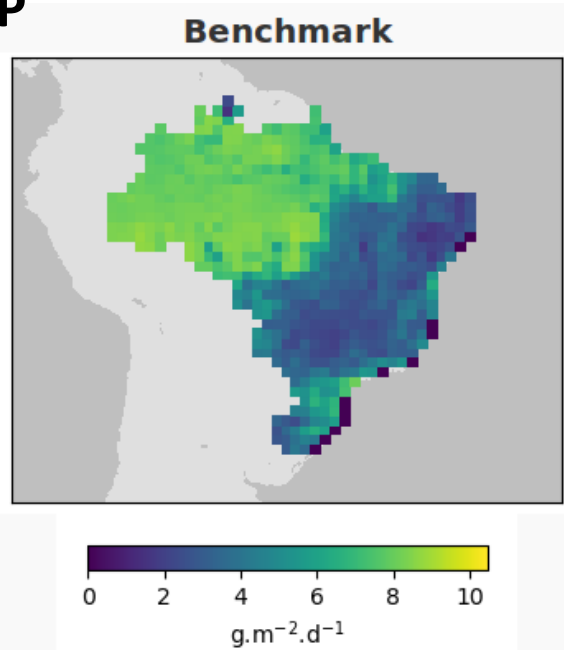
- Benchmark is CARDAMOM
- Stippling → models fall within +/- 10% of benchmark

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)