JULES global physical configuration

PL Vidale

National Centre for Atmospheric Science

Dept. of Meteorology, University of Reading

The TEAM:

Patrick McGuire (Uni Reading / NCAS-CMS)

Carolina Duran Rojas (Uni Exeter)

Eddy Robertson (Met Office)

Omar Muller (Uni Reading, PRIMAVERA)

The broader team developing our **JULES National Capability**:

Patrick C. McGuire (*U. Reading, NCAS*), Pier Luigi Vidale (*U. Reading, NCAS*), Eleanor Blythe (*CEH*), Carolina Duran Rojas (*U. Exeter*), Anna B. Harper (*U. Exeter*), Grenville M.S. Lister (*U. Reading, NCAS*), Toby Marthews (*CEH*), Alberto Martinez-de la Torre (*CEH*), Omar V. Müller (*U. Reading, U. Nacional del Litoral*), Eddy Robertson (*Met Office*), Anne Verhoef (*U. Reading*), Charles J. R. Williams (*formerly U. Reading, now U. Bristol*), Karina E. Williams (*Met Office*)

Configurations as attractors for the developer and end-user community

- JULES has enjoyed tremendous development over the last ten years
  - Updated and/or new science modules/parametrisations, e.g. radiation, O_3
  - New capabilities (e.g. data assimilation, crops, wetlands, nutrient cycles)
  - Code management, documentation, parallelisation, NetCDF, etc.
- However, similar to other community models, we have started to run into some difficulties, e.g. when answering these questions:
  - Is JULES any good? How does it stand internationally?
  - I have developed science module X: why is it not adopted by the community?
  - I need to write a new proposal / new paper: which JULES should I use?
  - **Our community requires a definition of what JULES is.**
- Some of these issues can be addressed by:
  1. defining and adopting common scientific configurations and
  2. jointly and regularly assessing the scientific performance of JULES, both nationally and internationally (against new observational data, other models etc.)

Which JULES configuration for what purpose?

FLUXNET

Cheap, versatile → large ensembles possible

Easiest to operate (e.g. on a PC)

Verified by fluxes, easiest to assess

Only relevant at local (site) scale

Crucial resource for model development

Global offline

Relatively cheap and easy to operate
Driven by observations (e.g. WFDEI)
Does not suffer from GCM meteo biases

Relevant at large scale

Ensembles are affordable

Moderately easy to assess, but range of suitable variables smaller than FLUXNET

Global Coupled

Most relevant to Weather and Climate modelling, prediction, consistent

Very expensive and requires a supercomputer

Strongly affected by GCM quality: (atmospheric/oceanic/cryosphere) biases

Hardest to assess, as feedbacks are all active

Each has variants, depending on complexity, e.g. dynamic vegetation on/off

Stakeholders, pathways to impact

In pursuing development of new science for JULES, our glory can be in just publishing a great Nature paper

However, as we are strongly steered to demonstrate impact, some important stakeholders are:

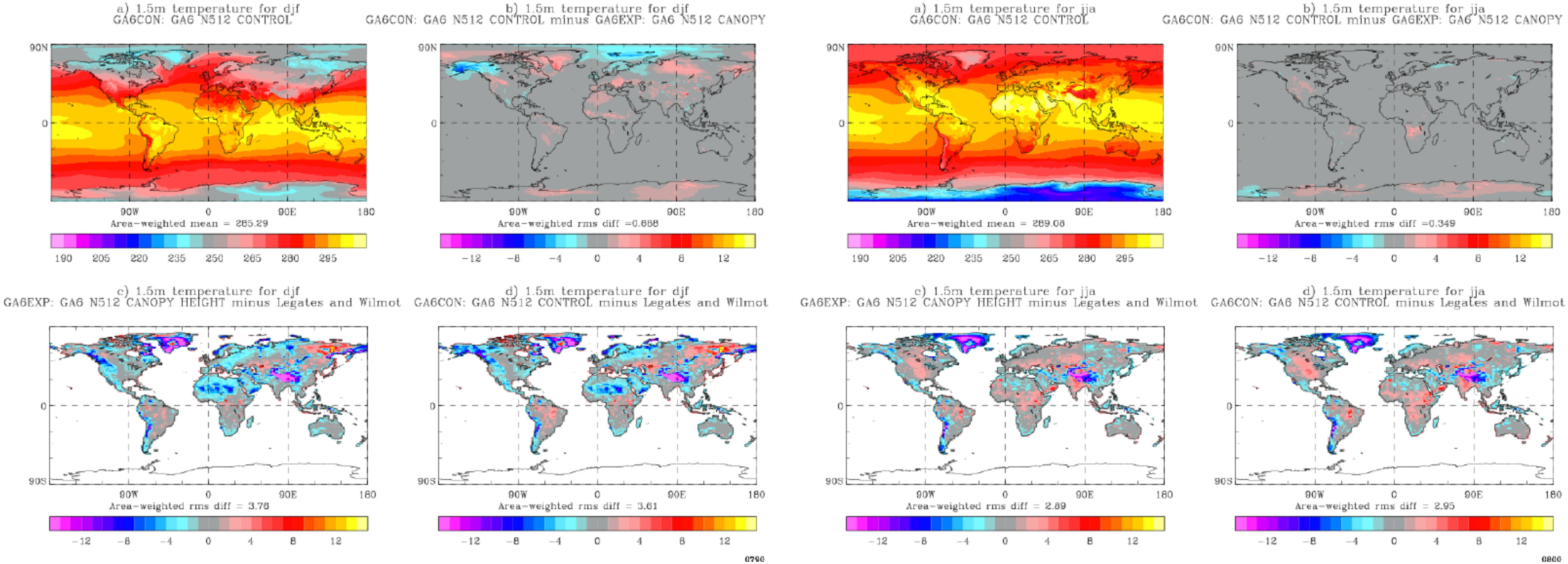
Stakeholder	Focus	Applications	Deliverable
Met Office / Hadley Centre	HadGEM3 GCM	NWP, seasonal, climate prediction	Improved land surface fluxes, climate
International science community	WCRP, GEWEX IPCC	CMIP, observational campaigns	Model intercomparisons, science papers
Government agencies	Hazard/impact prediction	Risk assessment	Flooding, drought, heatwave risk
Overseas Development	Multi-hazard	Extreme Rainfall → flooding, crop productivity, resilience	Integrated risk assessment
Business	Exposure/vulnerability	Catastrophe modelling	Loss estimates Opportunities for profit

So, we must develop and sustain our ability to insert our science into community models and to exercise these models in a complex, albeit still well-assessed way, at the process level, to know **how trustworthy our models are**. This requires a community approach alongside individual efforts

How good/bad is JULES? How can we improve it?

Experiment on the impact of re-defining canopy height from remote sensing:
JULES (GL6) coupled to HadGEM3-GA6

1.5 m temperature bias in DJF (left) and JJA (right)



This is an insane way of developing JULES: the experiment is expensive, the <u>result is not robust</u>: I have learned nothing

A better way

- Define a global JULES configuration that follows GL6 as closely as possible:
  - Same boundary conditions
  - Same flags for physics options etc. etc.

  - **Major deviation**: use of WFDEI meteorology forcing, instead of HadGEM3-GA6 meteorology
    - This also affects the spin-up, hence the initial conditions
    - Danger: WFDEI (or any other such forcing datasets) is not necessarily in balance or conserving*, which can lead to drifts in soil moisture, snow cover etc.

- Run on JASMIN, which includes the ability to run an ensemble
- Find a way to assess the model. In this case, an example is the ILAMB tool.

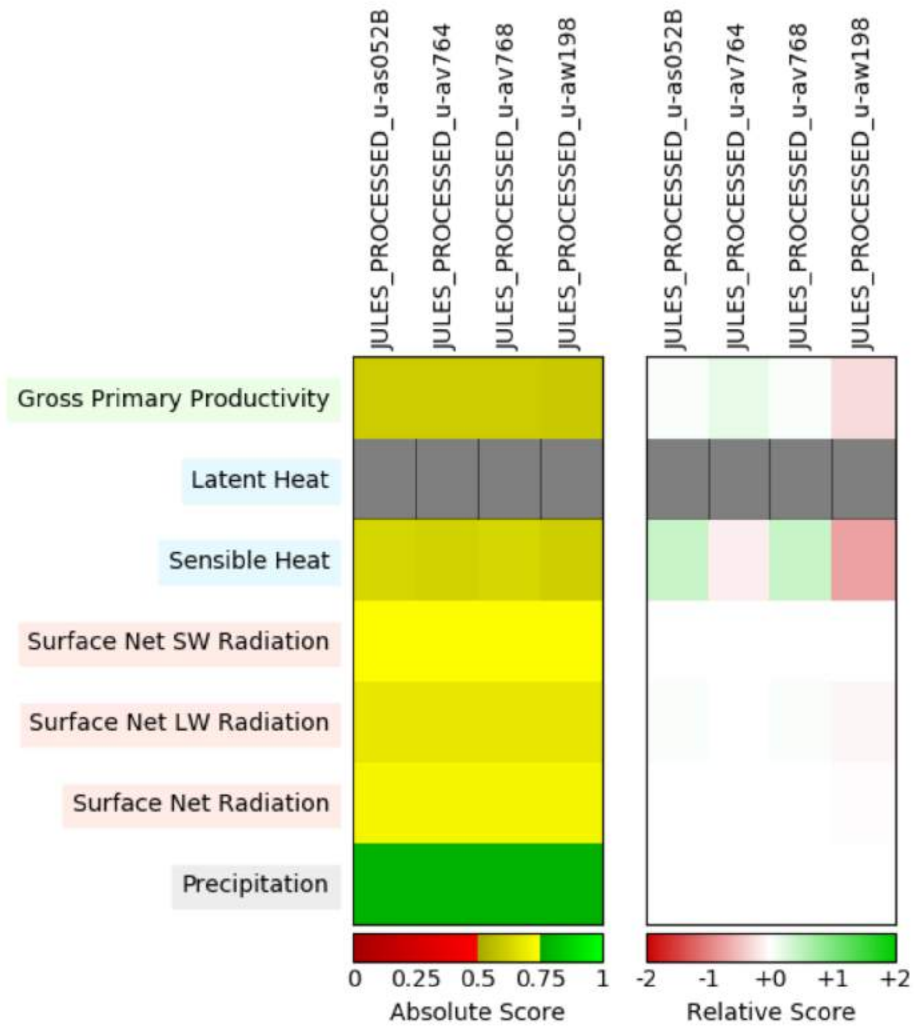
*GCMs are always wrong, albeit consistent!

The global physical configuration

- Start with a GL definition in HadGEM3, that is, broadly:
  - Focus is on fluxes of momentum, sensible heat, latent heat
  - Vegetation is prescribed, carbon fluxes are diagnosed, albeit do not contribute to vegetation dynamics
  - Most ESM feedbacks are off, e.g. nutrient cycles, ozone damage etc.
- Simulations are for the historic period: 1979-2015
- Global grid at 0.5 degrees, driven by WFDEI meteorology
- Since the Initial Conditions (ICs) for such a configuration are unknown, start with a 100 year spin up to a reasonable convergence (0.1 C and 1% of soil moisture)

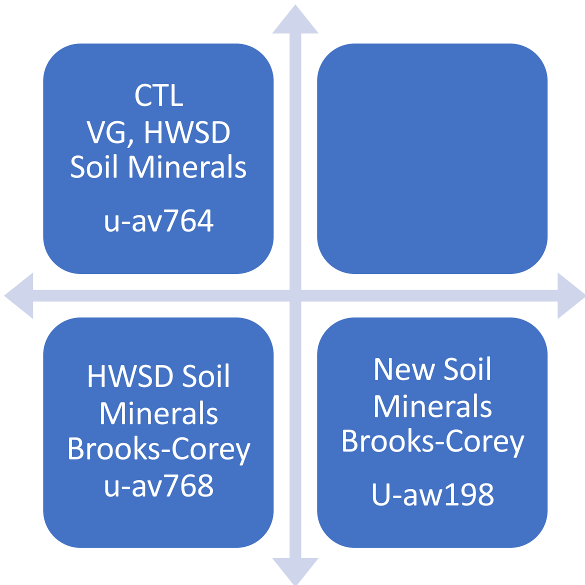
- For <u>next</u> configuration, then add:
  - Soil mineral maps
  - Improvements/fixes from recent papers, e.g. Van den Hoof et al. 2013.

Examples of ILAMB output: overall



The suites:

SPIN UP	SOIL	JULES GLOBAL	ILAMB
35 yrs	BC, old min	u-as052B	u-ba594D
100	VG, old min	u-av764	u-ba599
100	BC, old min	u-av768	u-ba600
100	BC, new min	u-aw198	u-ba601



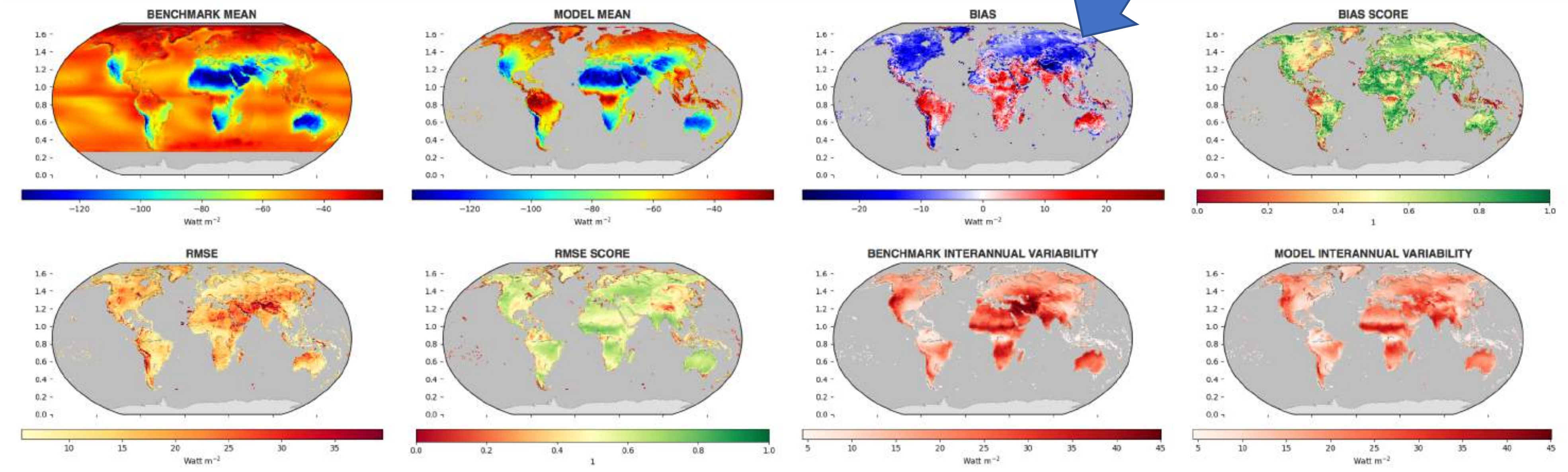
Examples of ILAMB output: surface Long Wave

Globe

	Download Data	Period Mean (original grids) [Watt m-2]	Model Period Mean (intersection) [Watt m-2]	Model Period Mean (complement) [Watt m-2]	Benchmark Period Mean (intersection) [Watt m-2]	Benchmark Period Mean (complement) [Watt m-2]	Bias [Watt m-2]	RMSE [Watt m-2]	Phase Shift [months]	Bias Score [1]	RMSE Score [1]	Seasonal Cycle Score [1]	Spatial Distribution Score [1]	Interannual Variability Score [1]	Overall Score [1]
Benchmark	[-]	-54.2													
JULES_PROCESSED_u-as052B	[-]	-70.2	-70.2	0.00	-69.1	-47.4	-1.16	16.0	0.962	0.60	0.54	0.87	0.98	0.81	0.72
JULES_PROCESSED_u-av764	[-]	-70.0	-70.0	0.00	-69.1	-47.4	-0.972	16.1	0.972	0.60	0.54	0.87	0.99	0.81	0.72
JULES_PROCESSED_u-av768	[-]	-70.2	-70.2	0.00	-69.1	-47.4	-1.16	16.0	0.961	0.60	0.54	0.87	0.98	0.81	0.72
JULES_PROCESSED_u-aw198	[-]	-69.8	-69.8	0.00	-69.1	-47.4	-0.779	16.0	0.958	0.60	0.54	0.87	0.99	0.81	0.72

Emitting too little LW at low latitudes
and too much at high latitude
Contributing to sfc T1.5m bias →

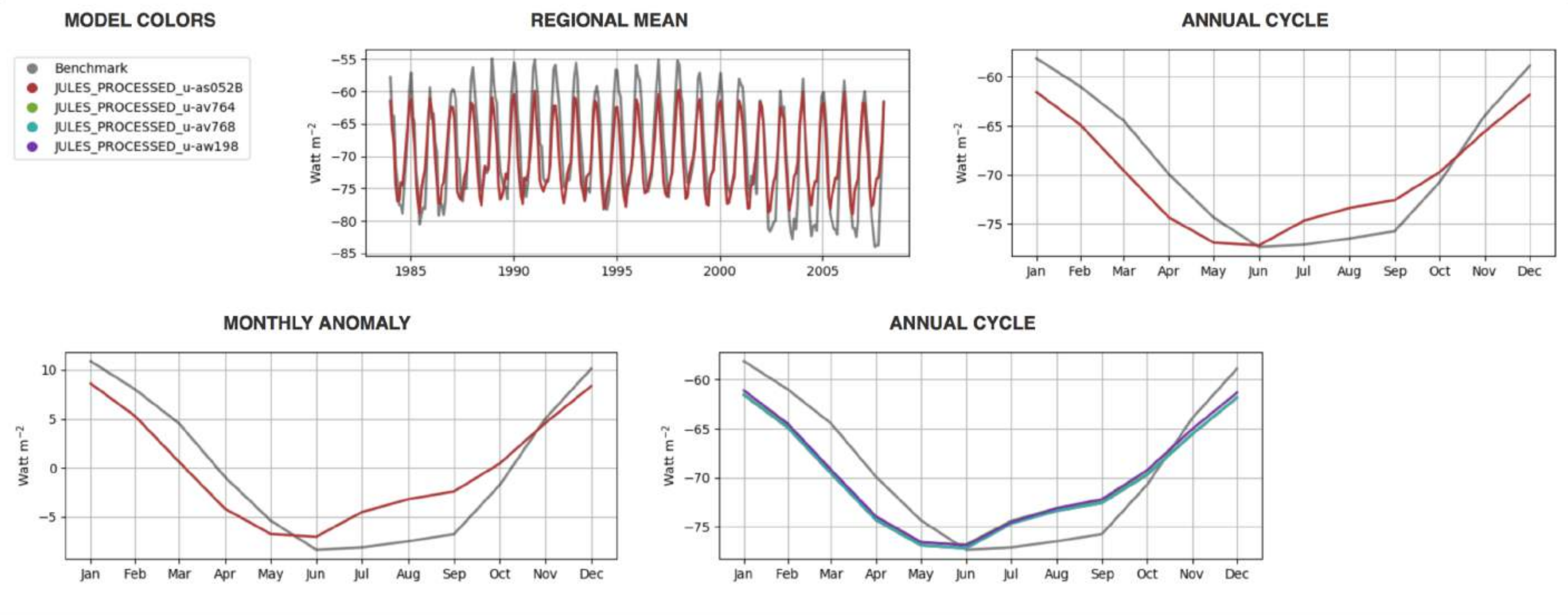
Temporally integrated period mean



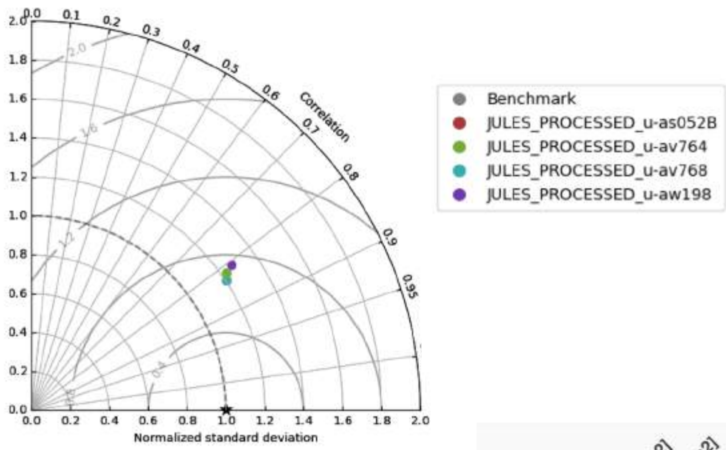
Longwave time series

Annual cycle depressed in some regions, mostly a winter bias
Overall good representation of interannual to decadal variability

Annual cycle is off: model starts to lose LW about 1 month too early
Snow dynamics, else the prescribed vegetation phenology?

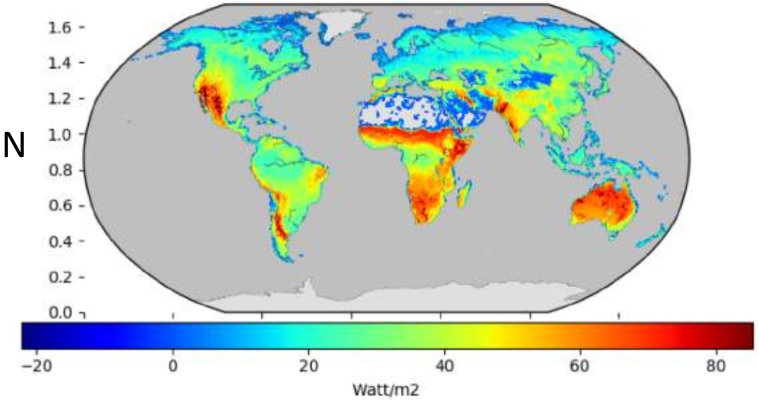


Examples of ILAMB output: sensible heat

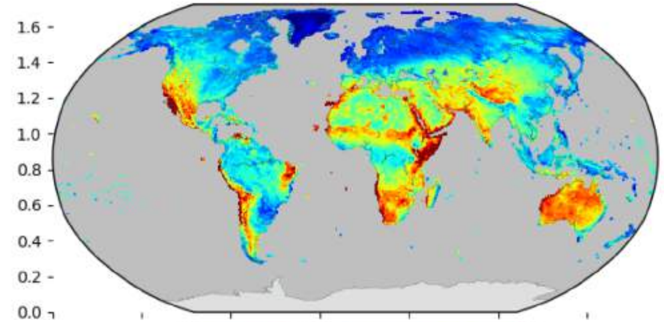


	Download Data	Period Mean (original grids) [Watt/m2]	Model Period Mean (intersection) [Watt/m2]	Model Period Mean (complement) [Watt/m2]	Benchmark Period Mean (intersection) [Watt/m2]	Benchmark Period Mean (complement) [Watt/m2]	Bias [Watt/m2]	RMSE [Watt/m2]	Phase Shift [months]	Bias Score [1]	RMSE Score [1]	Seasonal Cycle Score [1]	Spatial Distribution Score [1]	Overall Score [1]
Benchmark	[-]	34.3												
JULES_PROCESSED_u-as052B	[-]	28.6	29.0	26.2	34.3	36.3	-5.36	23.6	0.734	0.49	0.40	0.93	0.88	0.62
JULES_PROCESSED_u-av764	[-]	27.6	27.8	25.7	34.3	36.3	-6.49	24.6	0.798	0.47	0.39	0.92	0.87	0.61
JULES_PROCESSED_u-av768	[-]	28.6	29.0	26.2	34.3	36.3	-5.36	23.6	0.734	0.49	0.40	0.93	0.88	0.62
JULES_PROCESSED_u-aw198	[-]	27.7	27.9	25.9	34.3	36.3	-6.39	25.6	0.824	0.48	0.38	0.92	0.85	0.60

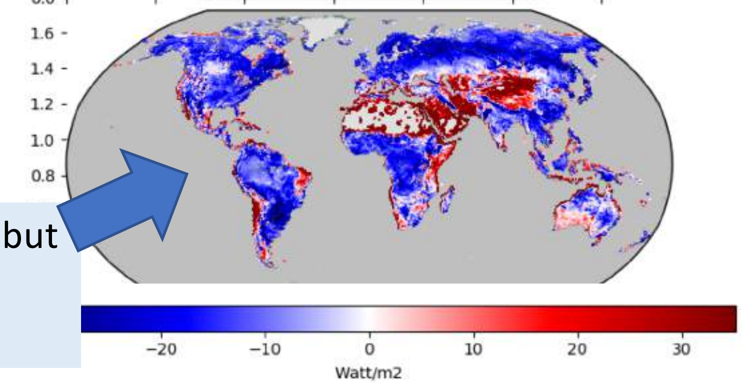
BENCHMARK MEAN



MODEL MEAN

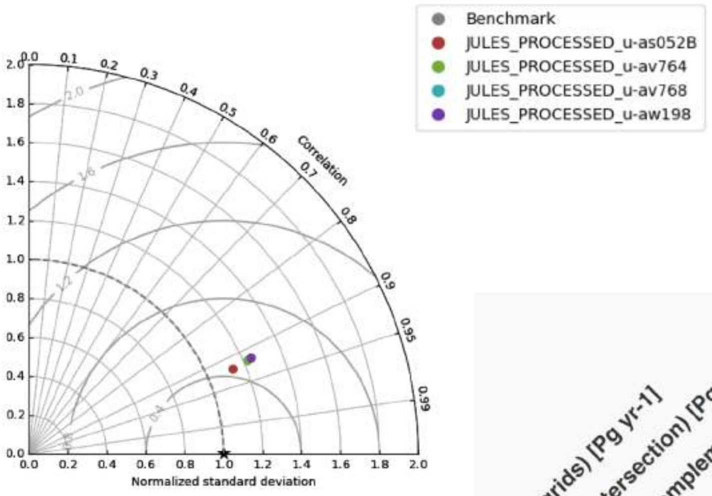


MEAN MODEL BIAS



Model seems too cold overall but
warmer at low latitudes
colder at high latitudes

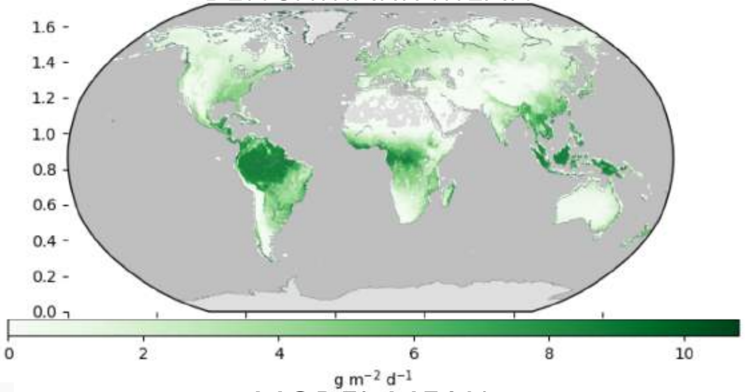
Examples of ILAMB output: GPP



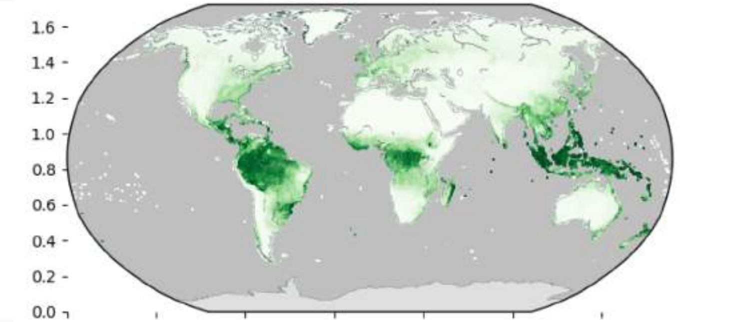
Production is depressed at high latitudes and exaggerated in the tropics
Regionally consistent with surface temperature bias

	Download Data	Period Mean (original grids) [Pg yr-1]	Model Period Mean (intersection) [Pg yr-1]	Model Period Mean (complement) [Pg yr-1]	Benchmark Period Mean (intersection) [Pg yr-1]	Benchmark Period Mean (complement) [Pg yr-1]	Bias [g m-2 d-1]	RMSE [g m-2 d-1]	Phase Shift [months]	Bias Score [1]	RMSE Score [1]	Seasonal Cycle Score [1]	Spatial Distribution Score [1]	Overall Score [1]
Benchmark	[-]	119.												
JULES_PROCESSED_u-as052B	[-]	115.	107.	7.75	119.	0.00477	-0.256	1.34	1.27	0.49	0.36	0.76	0.95	0.58
JULES_PROCESSED_u-av764	[-]	121.	113.	8.14	119.	0.00477	-0.133	1.36	1.33	0.47	0.38	0.74	0.92	0.58
JULES_PROCESSED_u-av768	[-]	115.	107.	7.75	119.	0.00477	-0.256	1.34	1.27	0.49	0.36	0.76	0.95	0.58
JULES_PROCESSED_u-aw198	[-]	121.	113.	8.16	119.	0.00477	-0.131	1.43	1.38	0.46	0.36	0.74	0.91	0.57

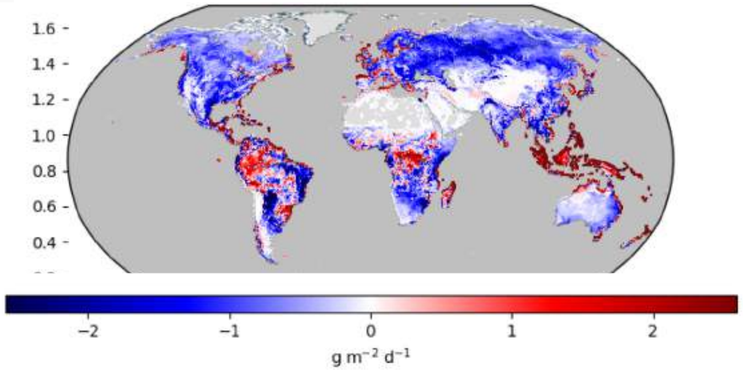
BENCHMARK MEAN



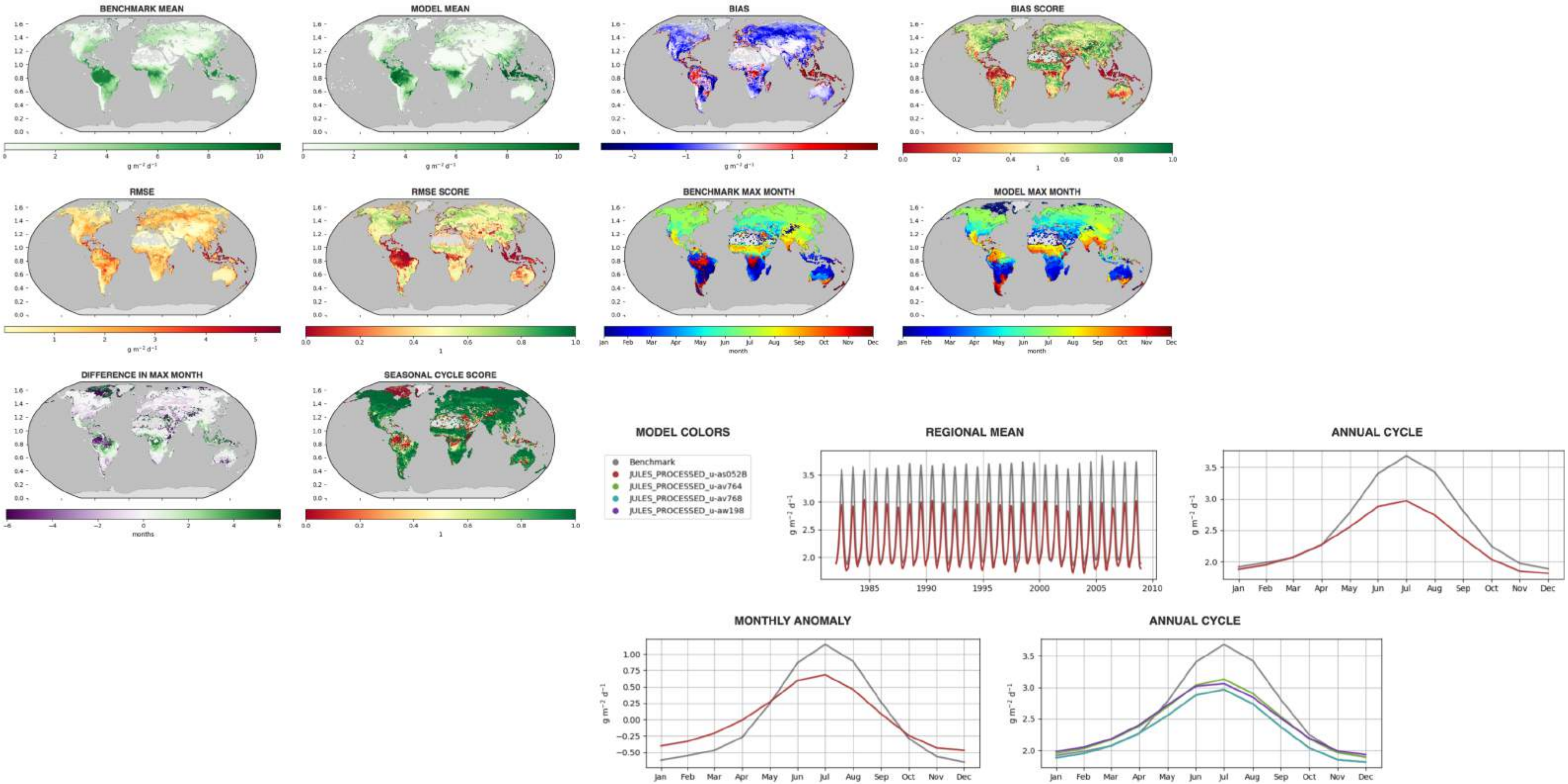
MODEL MEAN



MEAN MODEL BIAS

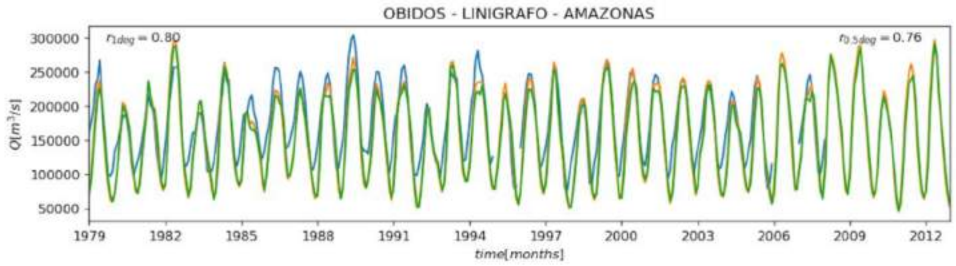


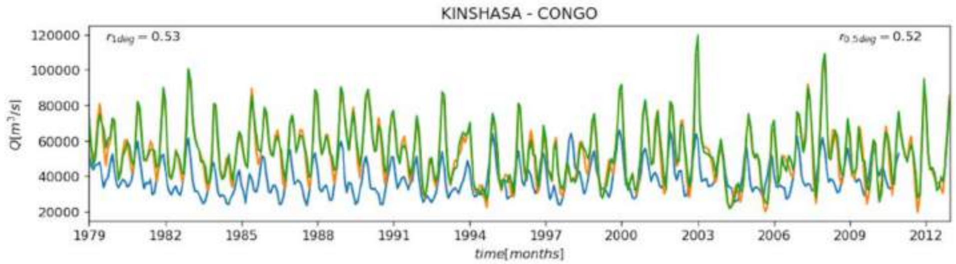
Each page provides lots more information…

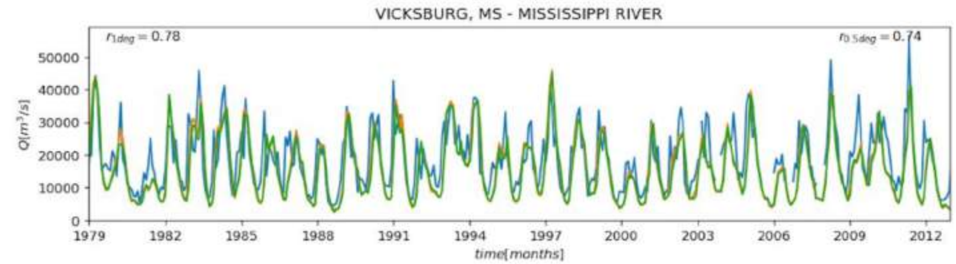


Hydrological cycle: river discharge

GRDC no.	River Name	Station Name	Lat	Lon	Period
3629001	Amazon	Obidos-Linigrafo	-1.9492	-55.5131	1950-2008
1147010	Congo	Kinshasa	-4.3	15.3	1950-2010
4127800	Mississippi	Vicksburg, MS	32.315	-90.9058	1950-2017
3265601	Parana	Timbues	-32.67	-60.71	1950-2014
2903420	Lena	Kusur	70.7	127.65	1950-2011
6742900	Danube	Ceatal Izmail	45.2167	28.7167	1950-2010







Opportunities for the JULES community

- Once a suite is defined, run and assessed on JASMIN, it becomes a community resource. JULES investigators can:
  - Use the data, plots etc. for analysis, intercomparisons, papers etc.
  - Use the data as reference for new experiments (e.g. my canopy height sensitivity study needed an official CTL run to compare against)
  - Use the data to initialise another model (e.g. put the ICs back into HadGEM3-GA6/GL6)
  - Use the **reference configuration as a starting point for newer configurations**, which will then influence decisions on future "official" configurations such as GL8, GL9 etc.
- Better collaboration, less waste of time, more publication
- Better foundations for developing a community model, including building and upkeeping our scientific reputation

Challenges for the JULES community

- Defining what an official configuration is: there are multiple stakeholders, with multiple <u>criteria for quality, success</u> etc. → must find common ground
- Maintaining the configurations against a changing JULES base: each configuration should give the same exact results under JULES X.x releases, as long as the science options are unchanged (and aware of bugs!):
  - RIGOROUS SEPARATION OF CODE BASE AND SCIENCE DEFINITIONS
  - SCIENTIFIC REPRODUCIBILITY, independent of model base version

- Requirements:
  - Small number of official configurations
  - Assessment tools suitable for each family of configurations, e.g. FLUXNET vs global
  - Publication of results on web page and shared data repository
  - Peer-reviewed publications with assessment of the quality of each configuration
  - Stable personnel resources
- Underlying technologies (e.g. FCM, Rose, CYLC) require training/re-training

What next

- Continue to improve the definition of the configurations and the "suites" available for the community
- Develop new capabilities, e.g. running JULES from different types of atmospheric forcings
- More active participation in international programmes, increasing JULES visibility
- Aim to involve entire community in definition of future JULES configurations used by key stakeholders such as MO/Hadley Centre, government agencies, businesses.

Roadmap for 2018-2019