The burning question: Are fire models suitable for climate attribution studies & projections?

Douglas Kelley, Chantelle Burton, Stacey New, Seppe Lampe, Joao Teixeira, Camilla Mathison, Maria Lucia Ferreira Barbosa, Inika Taylor, Eleanor Burke, Anna Bradley, Eddy Robertson, Robert Parker, Chris Jones

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Met Office Hadley Centre

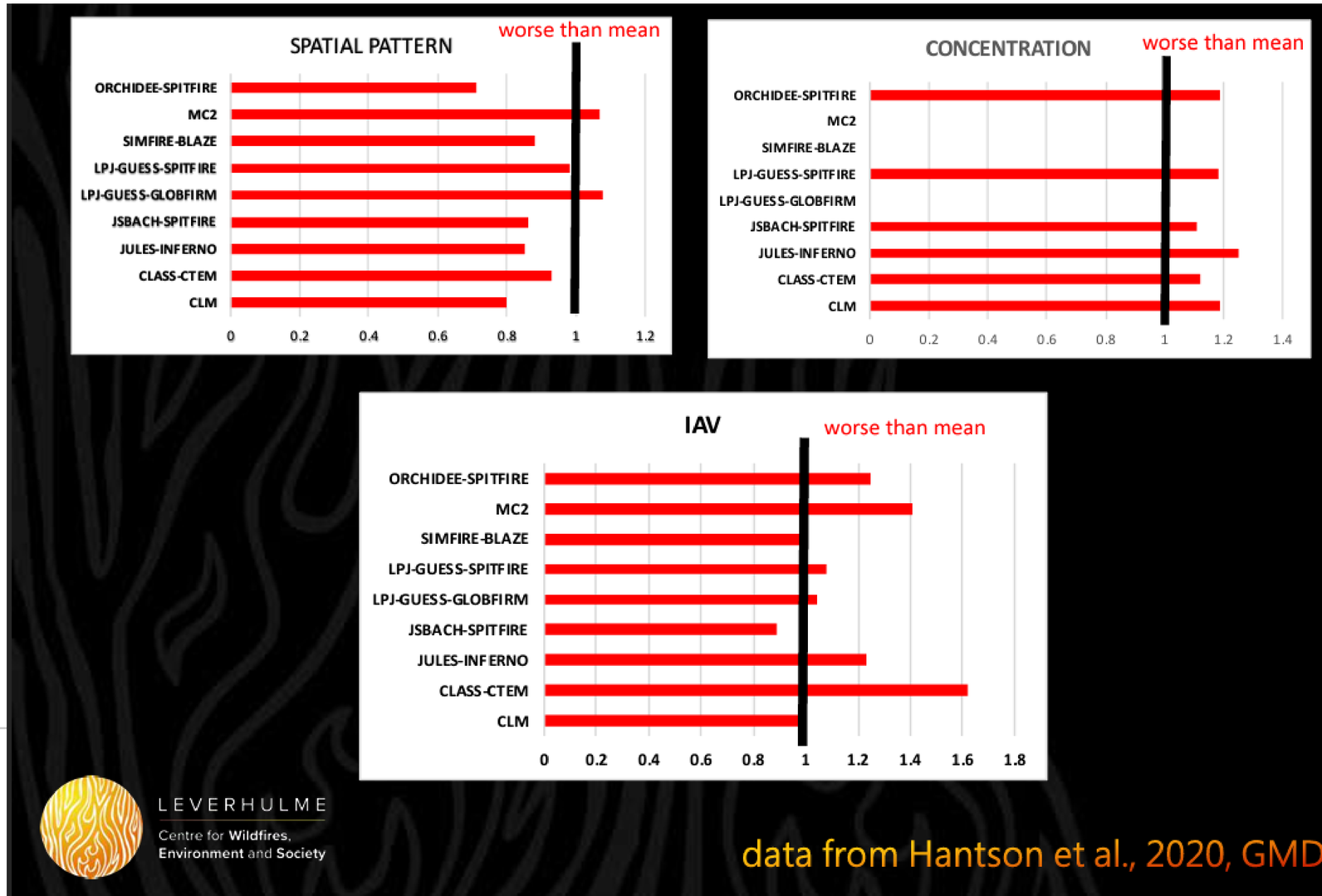
Is this in response to Sandys 2022 JULES talk?

Yes!

Shows big fire models performance issues

Given current model performance, what can we say about changing fire regimes?

How do we find this out?



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FireMIP model evaluation

- Simple metrics and datasets for general model evaluation
- Great for multi-model comparisons & quick model dev. checks

Biogeosciences, 10, 3313–3340, 2013
www.biogeosciences.net/10/3313/2013/
doi:10.5194/bg-10-3313-2013

Biogeosciences Open Access

A comprehensive benchmarking system for evaluating global vegetation models

D. I. Kelley[1], I. C. Prentice[1,2], S. P. Harrison[1,3], H. Wang[1,4], M. Simard[5], J. B. Fisher[5], and K. O. Willis[1]

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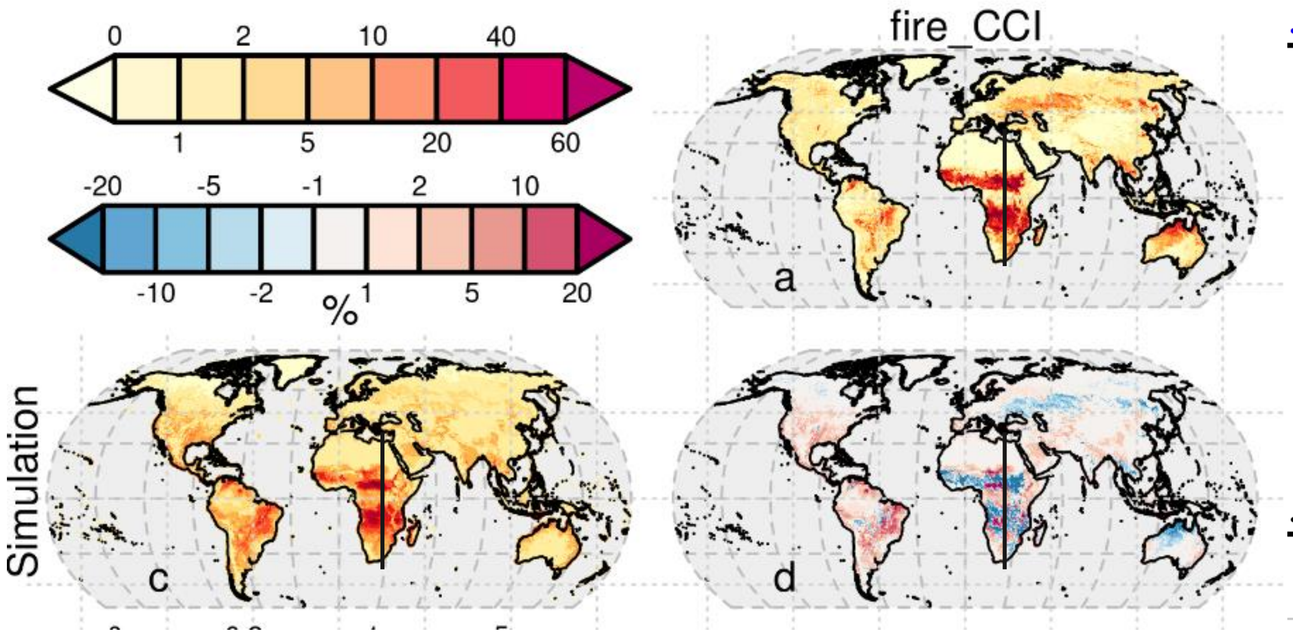
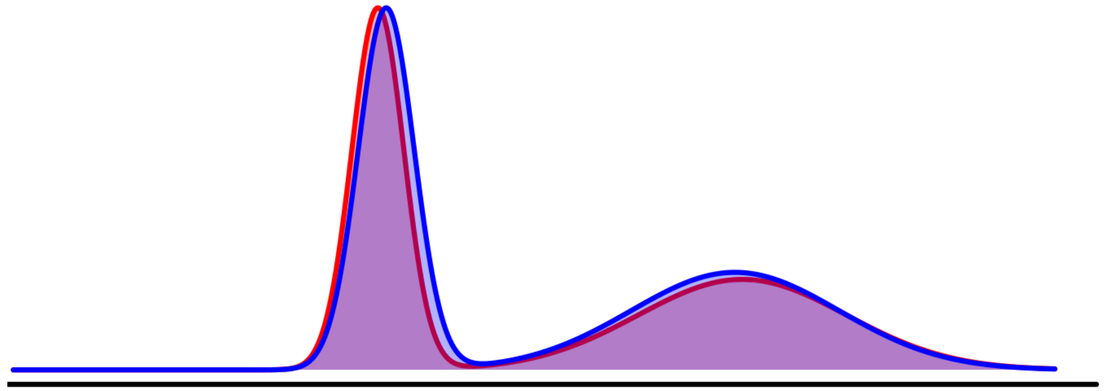
[2]Grantham Institute for Climate Change, and Department of Life Sciences, Imperial College, Silwood Park Campus, Ascot SL5 7PY, UK
[3]Geography & Environmental Sciences, School of Human and Environmental Sciences, Reading University, Whiteknights, Reading, RG6 6AB, UK
[4]State Key Laboratory of Vegetation and Environmental Change, Institute of Botany, Chinese Academy of Science, Xiangshan Nanxincun 20, 100093 Beijing, China
[5]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA

Metric	Equation	Limits	Use in this study
Normalised mean error (NME)	$\mathrm{NME} = \sum_i \lvert y_i - x_i \rvert / \sum_i \lvert x_i - \bar{x} \rvert$	0 – Perfect agreement 1 – Model performs as well as observational mean	For burnt fraction and fAPAR: annual averages, phase concentration, inter-annual variability.
Normalised mean squared error (NMSE)	$\mathrm{NMSE} = \sum_i (y_i - x_i)^2 / \sum_i (x_i - \bar{x})^2$	2 – complete disagreement for step 3 Infinity – complete disagreement for step 1 and 2	For runoff: annual averages, inter-annual variability For CO_2: phase concentration For NPP, GPP and height: annual averages
Mean phase difference (MPD)	$\mathrm{MPD} = (1/\pi) \arccos\left[\cos(\omega_i - \phi_i)/n\right]$	0 – in phase 1 – 6 months out (out of phase)	Assessing difference in seasonality for fAPAR, burnt fraction and CO_2
Manhattan metric (MM)	$\mathrm{MM} = \sum_{ij} \lvert q_{ij} - p_{ij} \rvert / n$	0 – Perfect agreement 2 – Perfect disagreement	Vegetation cover comparisons for life forms, tree, grassland, bare ground, evergreen vs. deciduous tree and broadleaf vs. needleleaf tree.
Squared chord distance (SCD)	$\mathrm{SCD} = \sum_{ij} \left(\sqrt{q_{ij}} - \sqrt{p_{ij}}\right)^2 / n$		

NME

$$NME = \frac{\sum_i^{cells} |model_i - observed_i|}{\sum_i^{cells} |\overline{observed} - observed_i|}$$

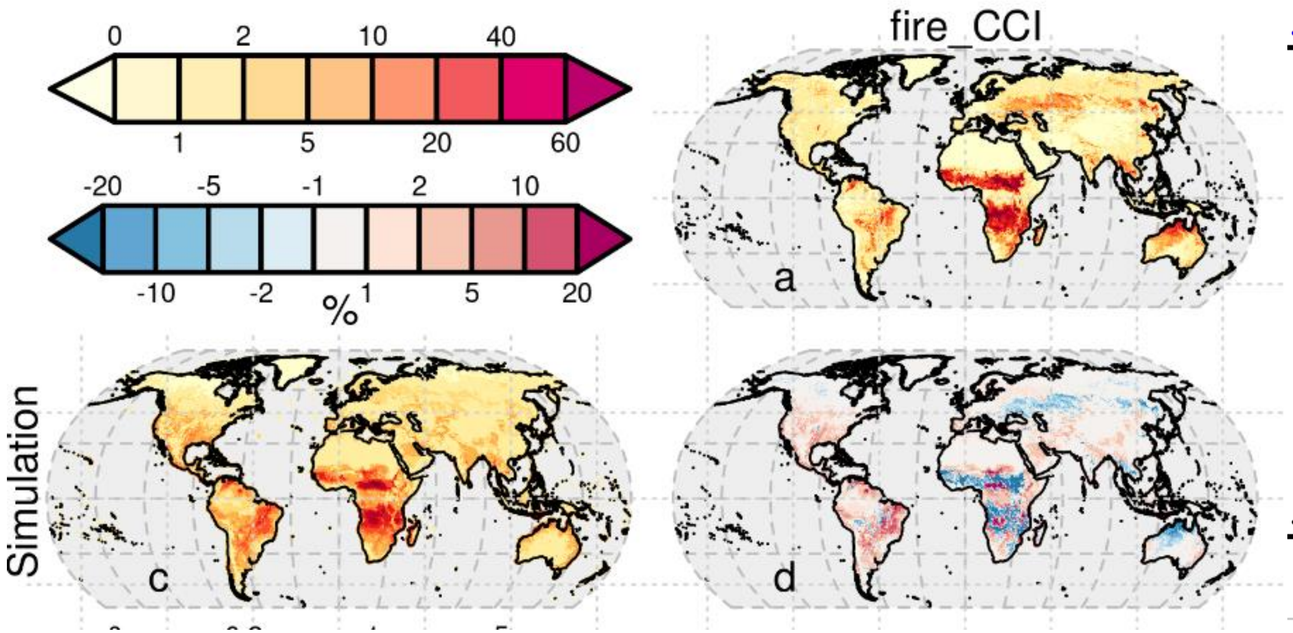


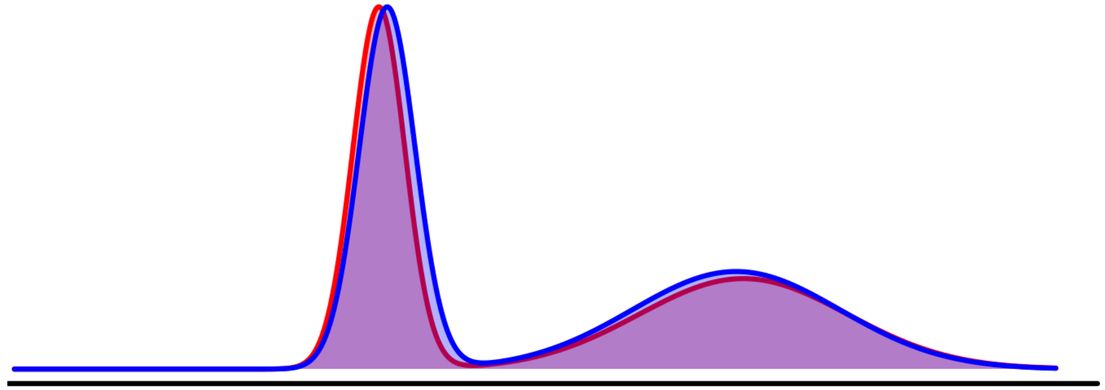


NME = 0.16

NME

$$NME = \frac{\sum_i^{cells} |model_i - observed_i|}{\sum_i^{cells} |\overline{observed} - observed_i|}$$





NME = 0.16

What eval doesn’t do yet

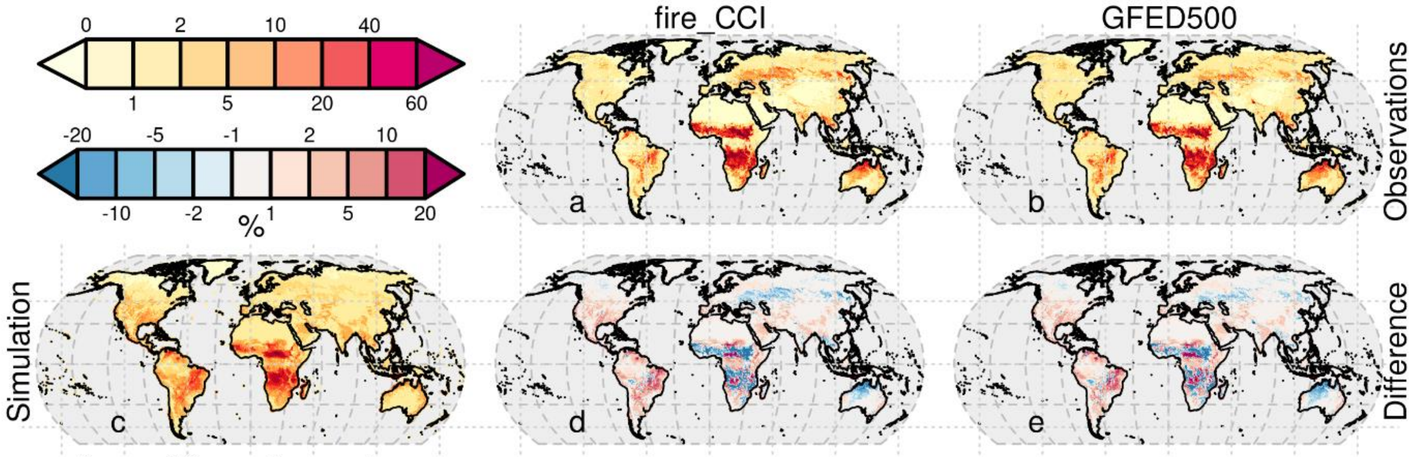
- Targeted evaluation designed to test specific applications
- Metrics unforgiving for small spatial mismatches
- Poor sampling of observational uncertainty
- Doesn’t really test for inter-annual variability
- No test for long-term trends/changes in fire.
- Test the effects of fire on impacts.

Criteria for climate attribution, future fires, changing impacts and wildfire occurrence

Application				Criteria	
At	FF	Im	Wld		Over region
Y	Y		Y	Spatial distribution of fires	
		Y		Spatial distribution of impacts	
Y	Y	Y		Reproduces trends in burnt area	
Y			Y	Captures inter-annual variability of fire	
			Y	Captures extremes in variability	
		Y		Reproduces trends in impacts over region	
		Y		Impacts trend is better with vs without fire	

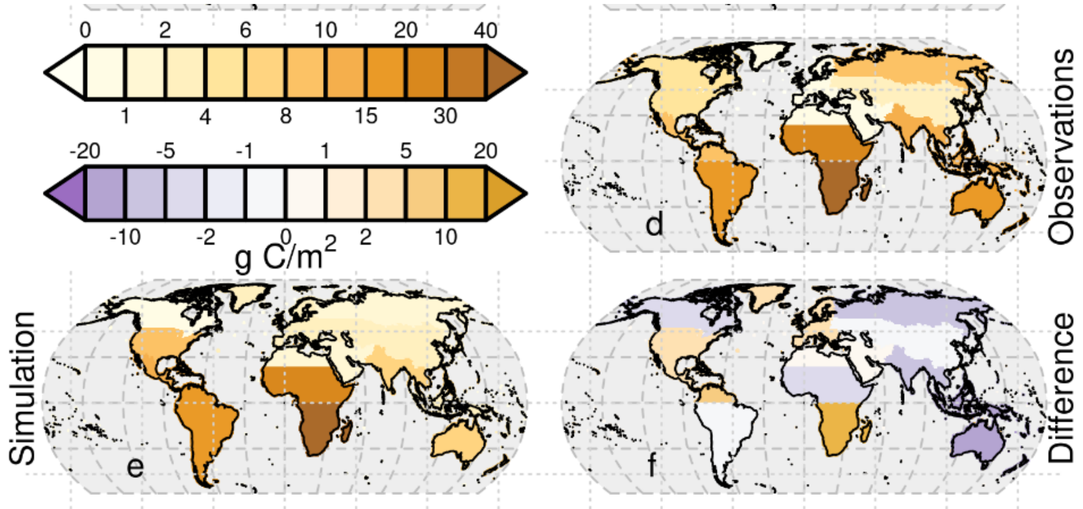
Spatial distribution of burnt area

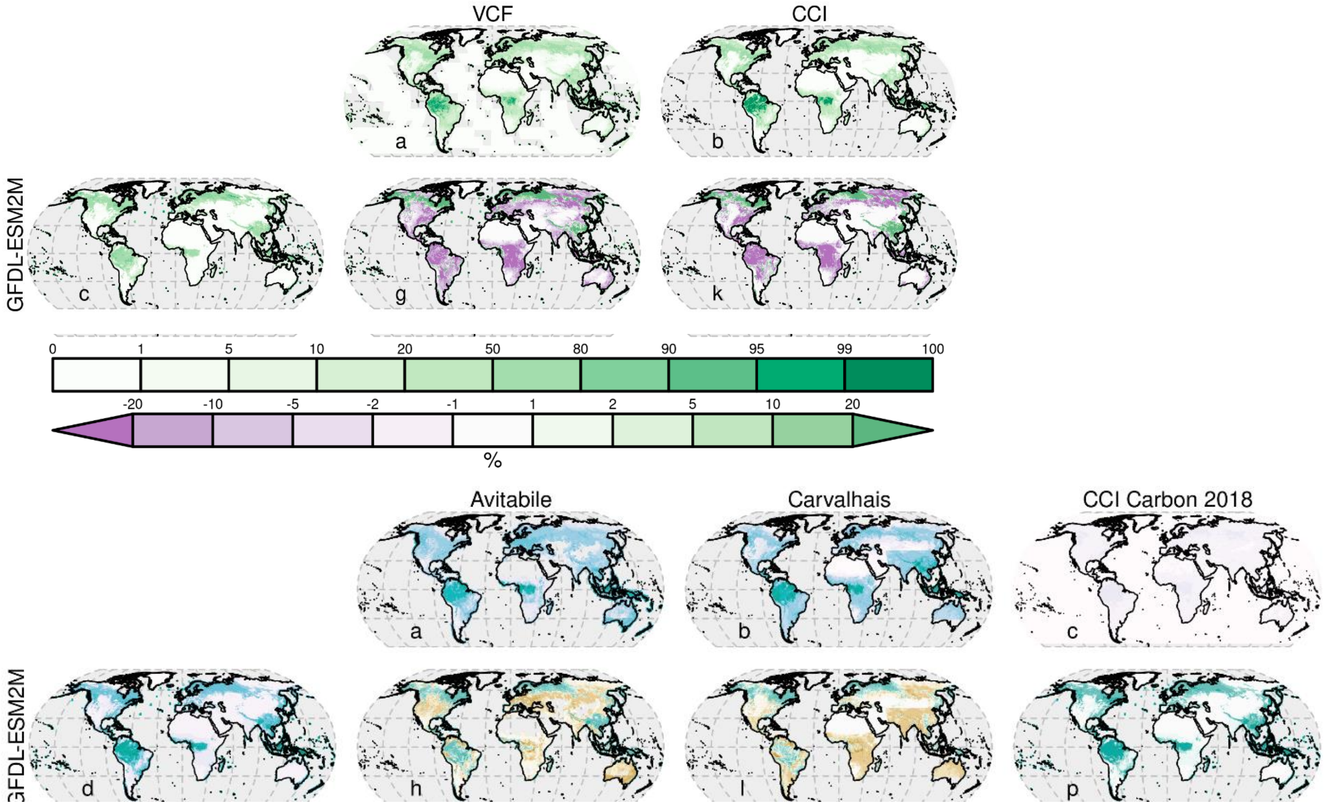
		GFED4s	Fire CCI	GFED 500	GFED 4	MCD45	Meris	Combined
By grid		0.66	0.67	0.72	0.81	0.79	0.8	0.7



Results show JULES-ES-ISIMIP2b evaluation (just for HadGEM2-ES in a single result)

Spatial distribution of impacts – i.e Fire emissions, vegetation carbon, tree cover





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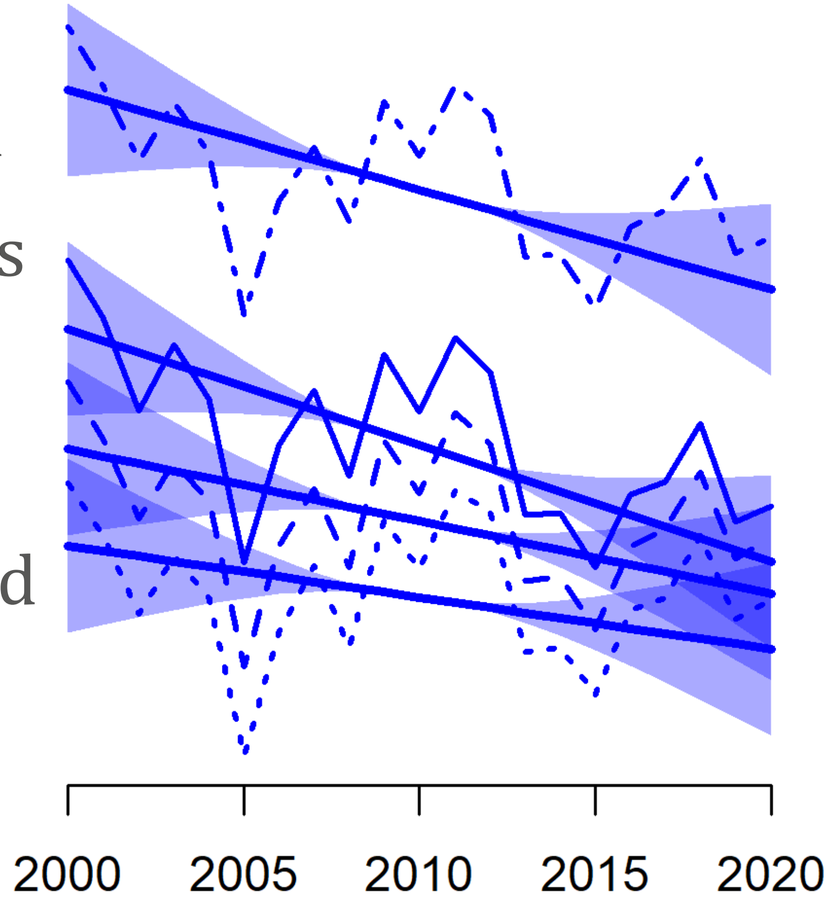
Reproduces trends in burnt area

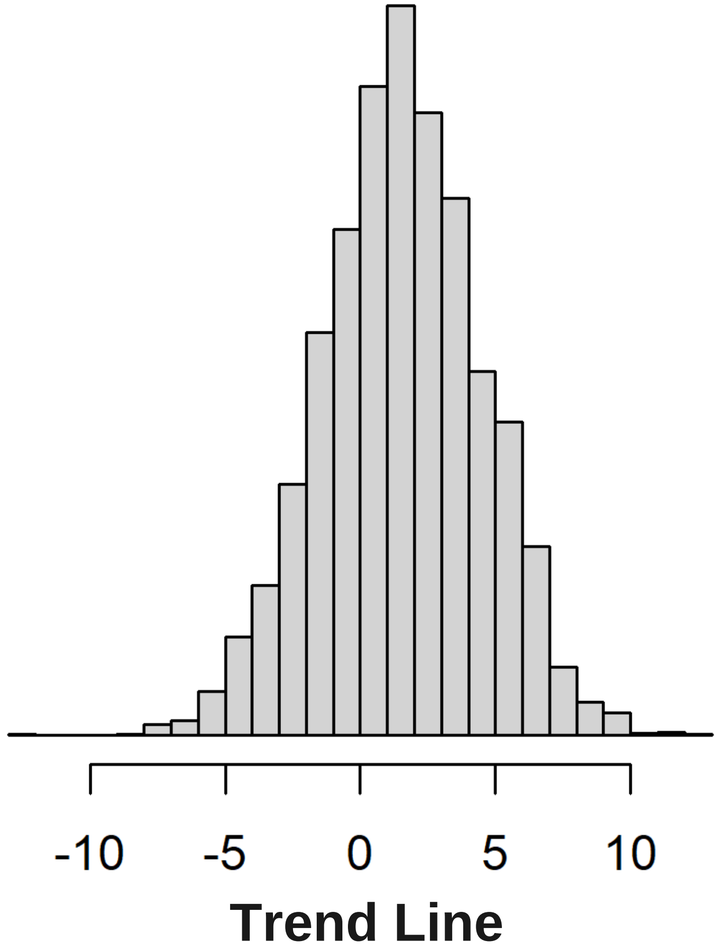
Obs. fire trends are very uncertain

From noisy process

From multiple products

We test if simulated trends are within this range





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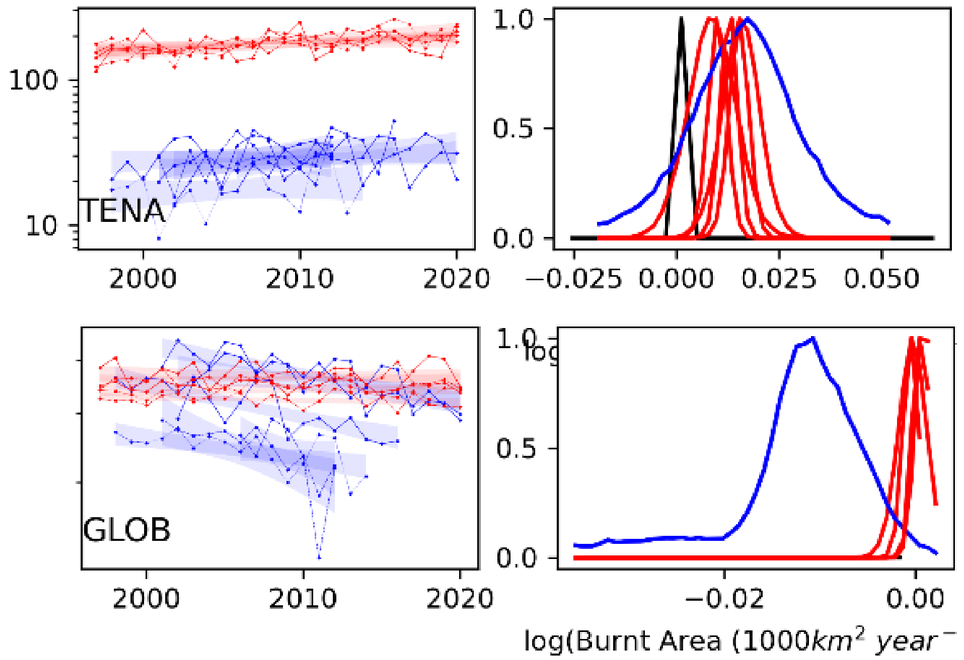
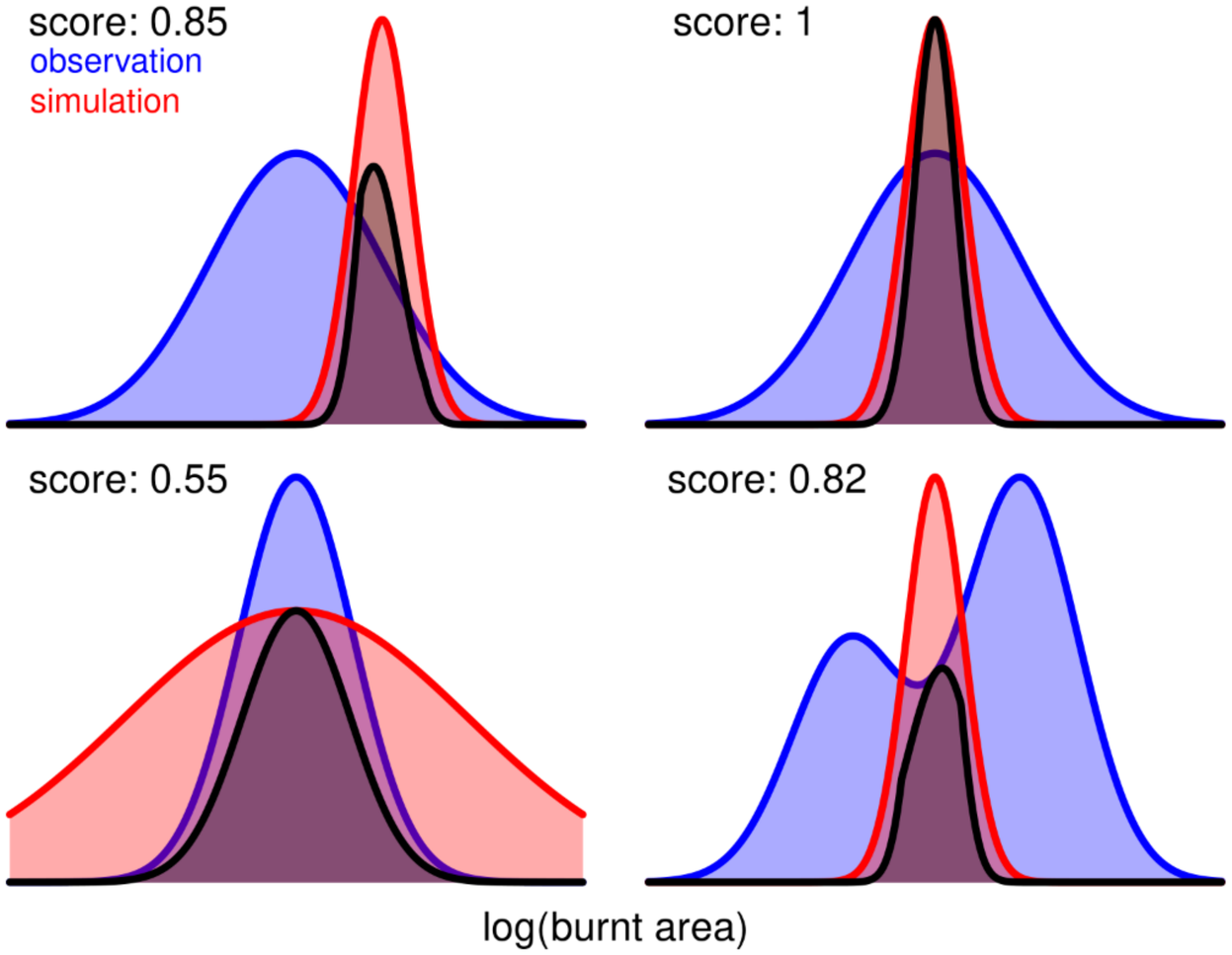
Benchmarking when changes in fire over time is important





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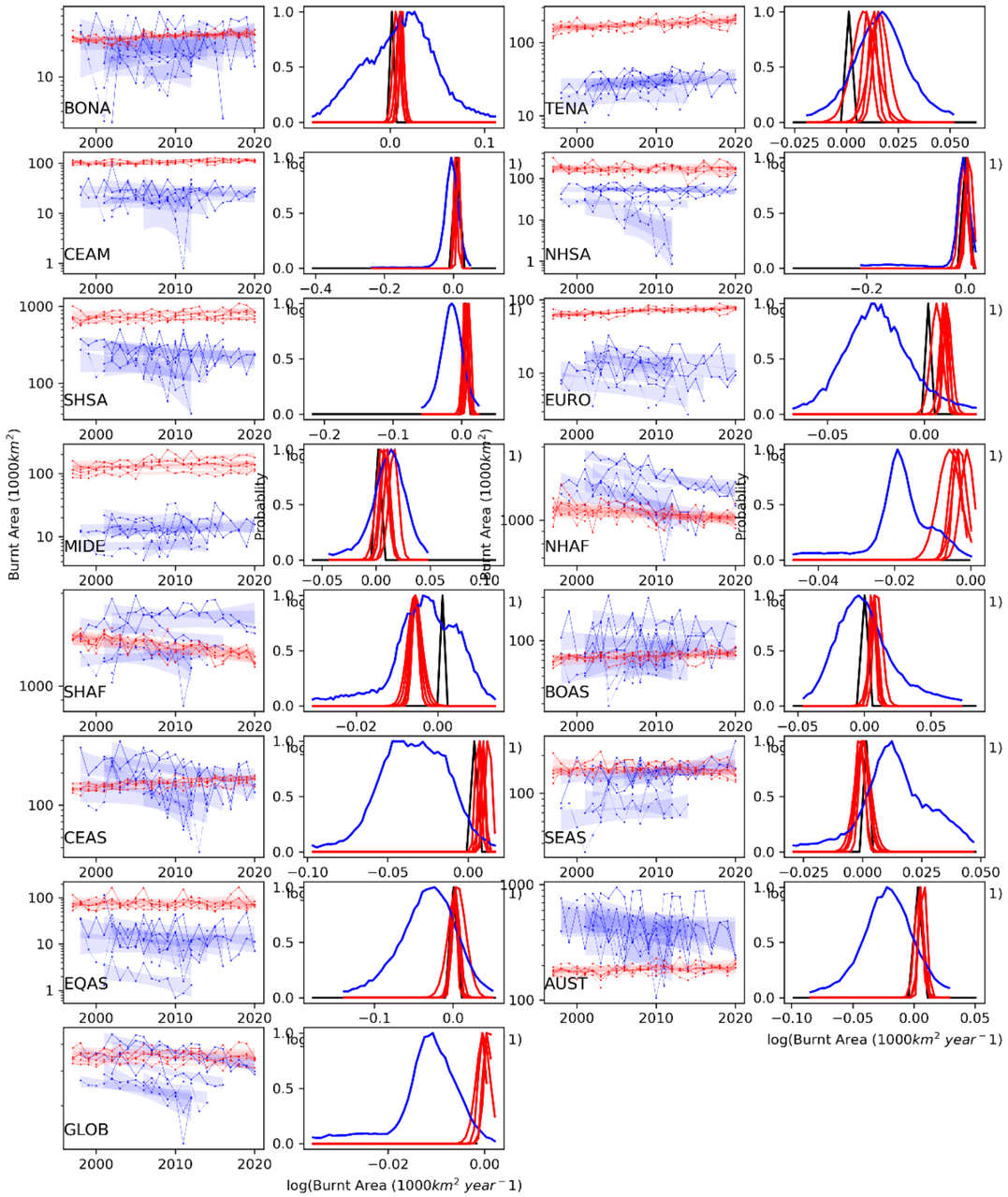
Gradient Overlap Metric

	Burnt Area					Fire emissions				
	Observations		*Model*			*Observations*		*Model*		
	10%	*90%*	*10%*	*90%*	*overlap (%)*	*10%*	*90%*	*10%*	*90%*	overlap
BONA	-0.057	0.077	0.0026	0.015	99.94	-0.021	0.069	0.0067	0.033	99.08
TENA	-0.011	0.044	0.0071	0.022	99.53	-0.018	0.042	0.004	0.037	94.11
CEAM	-0.072	0.025	0.0028	0.0097	77.46	-0.019	0.031	-0.0032	0.0088	97.75
NHSA	-0.27	0.013	-0.0089	0.0064	89.77	-0.041	0.0056	-0.025	0.017	77.44
SHSA	-0.12	0.016	0.0017	0.01	64.33	-0.055	0.018	-0.003	0.018	72.92
EURO	-0.055	0.016	0.006	0.015	43.15	-0.088	-0.0073	-0.0005	0.022	29.7
MIDE	-0.029	0.075	-0.0049	0.012	94.94	-0.031	0.014	-0.0098	0.0029	95.04
NHAF	-0.046	-0.0056	-0.0044	0.0015	27.44	-0.031	-0.014	-0.013	0.0027	18.48
SHAF	-0.024	0.0088	-0.0083	-0.0032	97.31	-0.0046	0.01	-0.009	0.001	58.56
BOAS	-0.036	0.059	0.0018	0.01	92.02	-0.053	0.049	-0.0054	0.011	98.03
CEAS	-0.086	-0.0013	0.0083	0.015	33.48	-0.055	-0.0035	-0.0034	0.011	36.2
SEAS	-0.023	0.04	-0.0046	0.0032	71.64	-0.0041	0.038	-0.0045	0.011	77.81
EQAS	-0.13	0.024	-0.0074	0.0064	87.16	-0.078	0.056	-0.013	0.0086	98.34
AUST	-0.07	0.025	-0.003	0.0076	72.66	-0.084	0.032	-0.006	0.013	85.89



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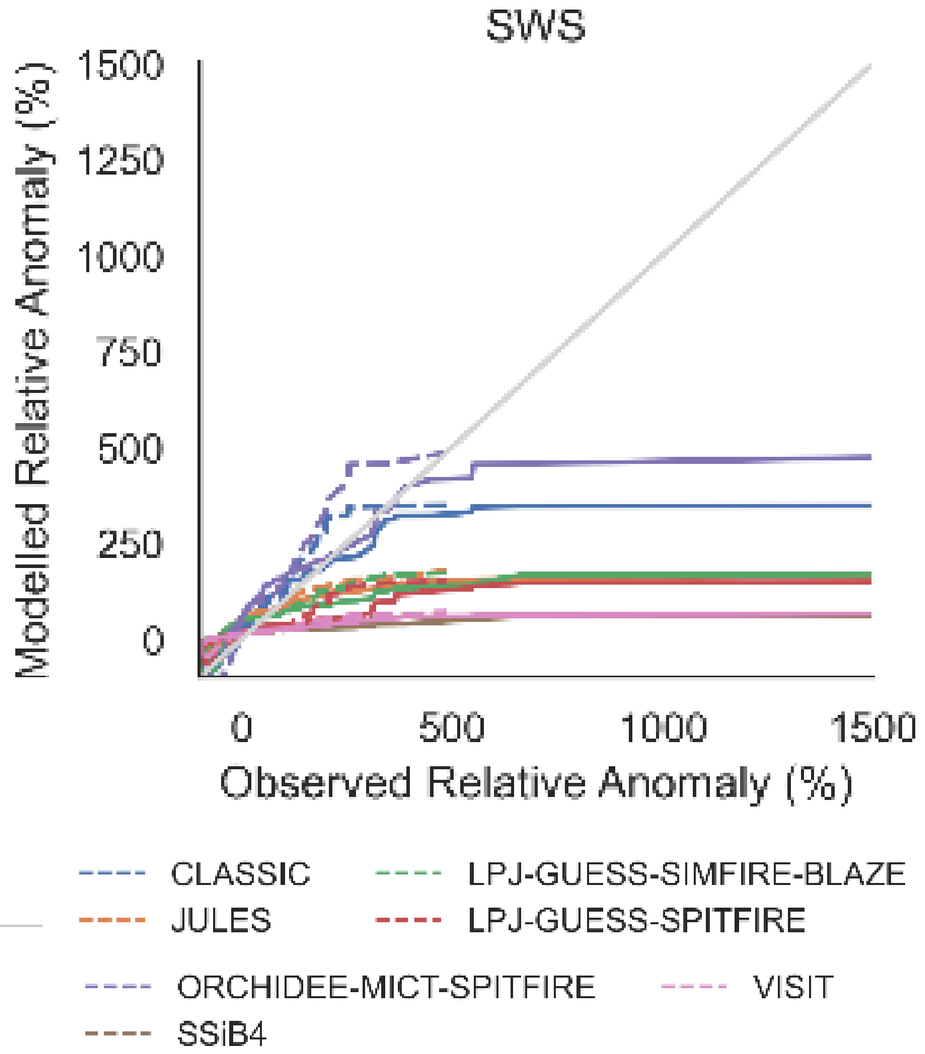
Captures extremes in variability

- From Burton & Lampe et al. (pre-print)
- Where do models burnt area distributions agree with Observed?



Criteria for climate attribution, future fires, changing impacts and wildfire occurrence

Application				Criteria	
At	FF	Im	Wld		Over region
Y	Y		Y	Spatial distribution of fires	Y
		Y		Spatial distribution of impacts	Y
Y	Y	Y		Reproduces trends in burnt area	Y
Y			Y	Captures inter-annual variability of fire	Sometimes
			Y	Captures extremes in variability	N
		Y		Reproduces trends in impacts over region	Y
		Y		Impacts trend is better with vs without fire	Y

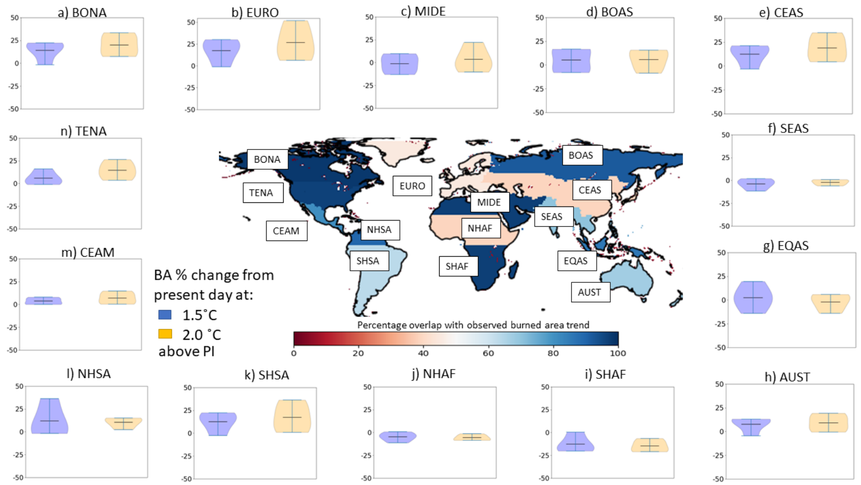
What we can use JULES-INFERNO for:

- Region-based/broad-scale fire changes
- How these impact tree cover and carbon

What JULES-INFERNO can't do (yet!):

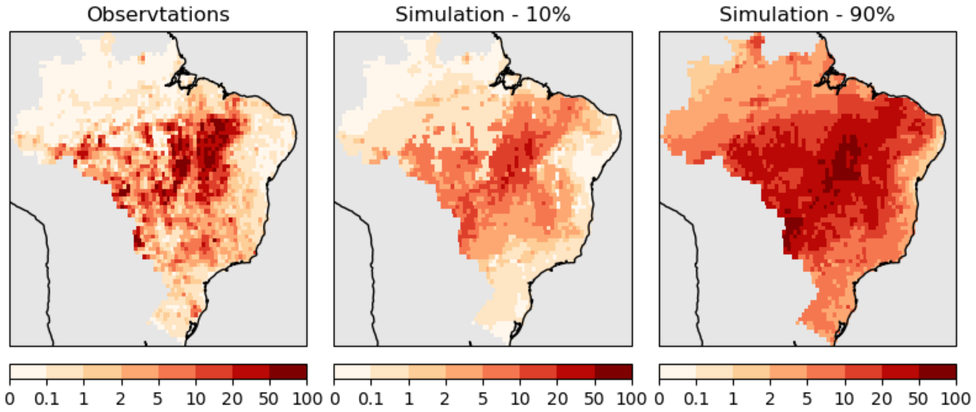
- Local scale (grid cell) fire-biogeography (though see Maria's talk)
- Extreme wildfire (though see ConFire)
- (By itself) fire attribution (though see FireMIP multi-model attribution)

JULES-firey tools

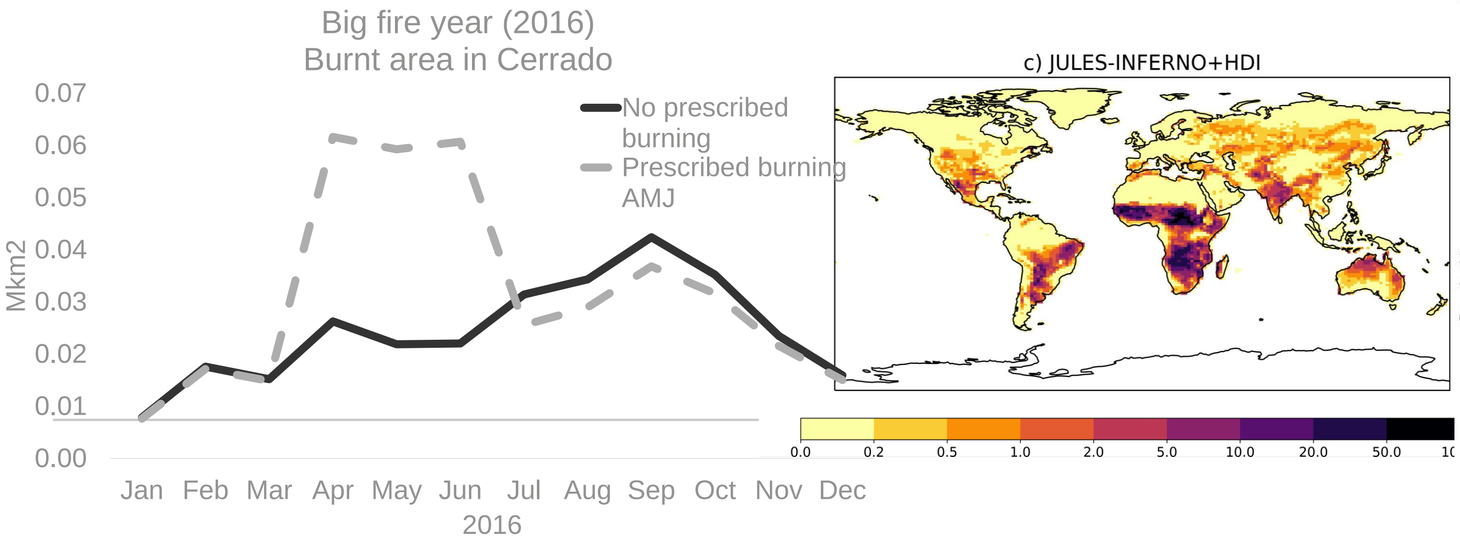


JULES-ES-INFERNO

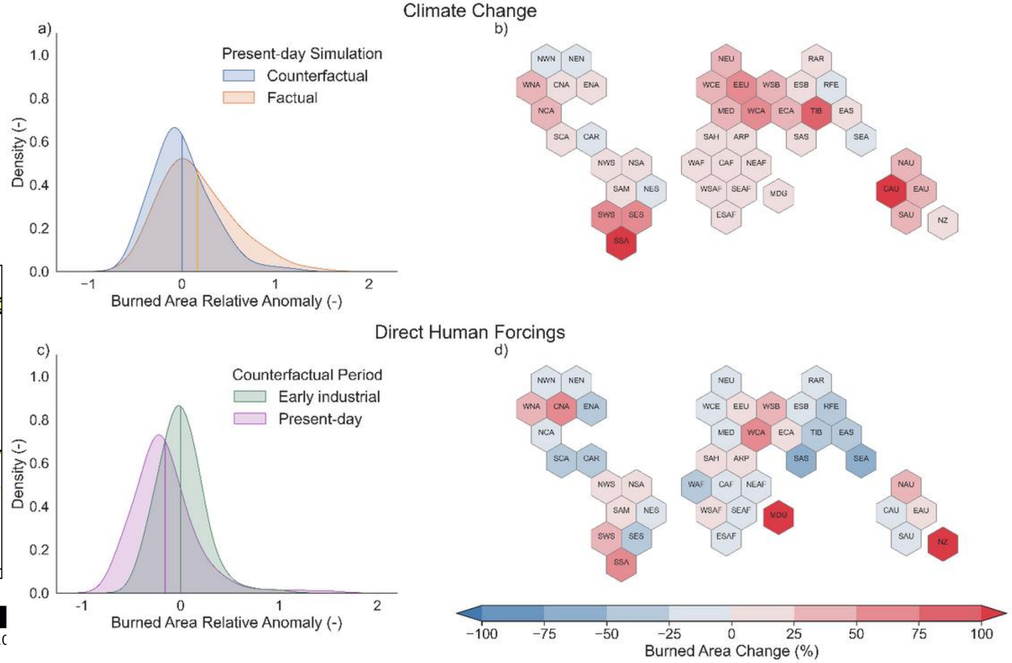
ConFire



FLAME – Empirical post-process



INFERNO developments



ISIMIP multi-model

How do know someone that uses fire models?

Help us collect good practices for using global fire model outputs

Interview

Doug Kelley
doukel@ceh.ac.uk
Chantelle Burton
chantelle.burton@metoffice.gov.uk
Stacey New
stacey.new@metoffice.gov.uk

Questionnaire

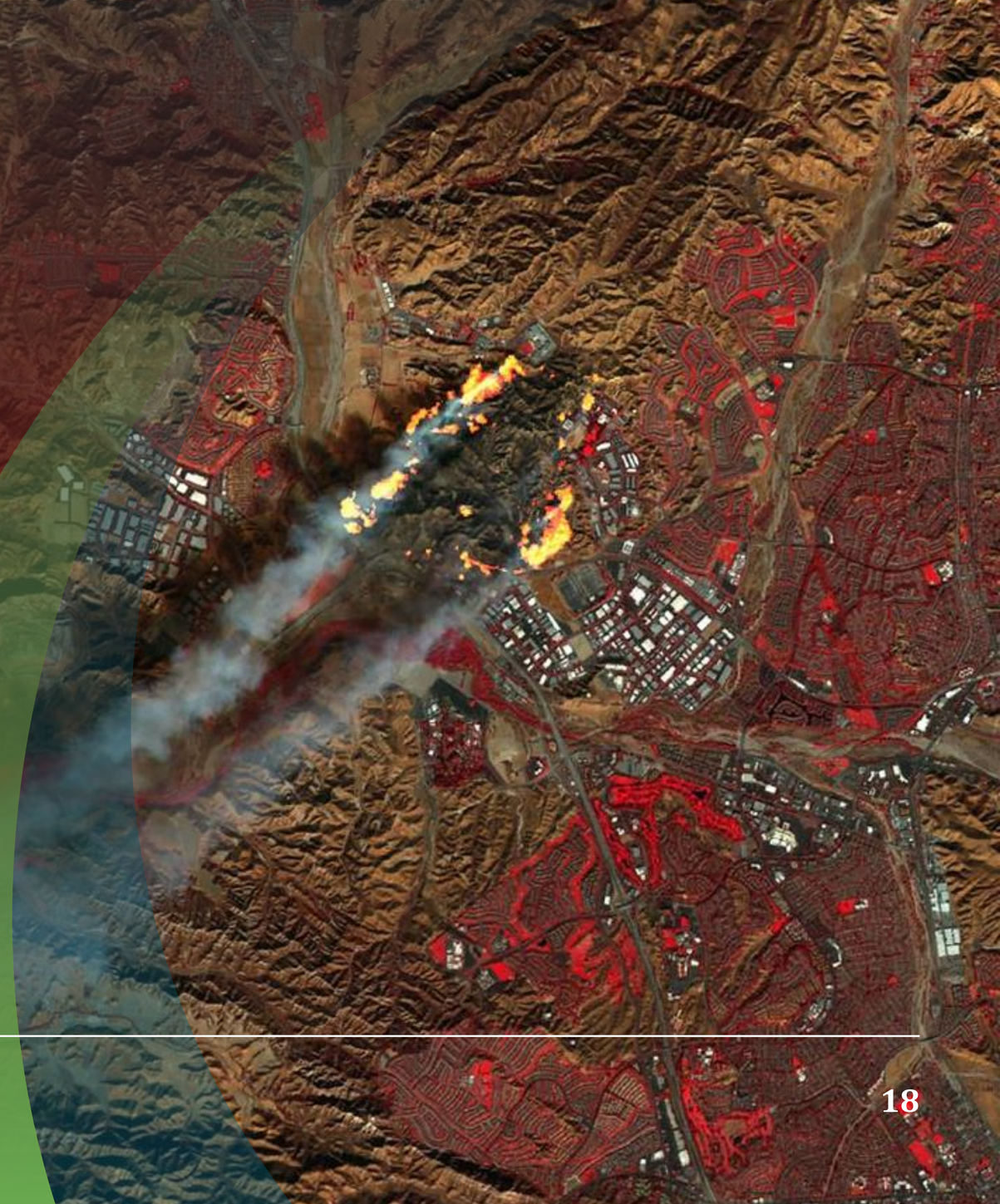
https://forms.gle/ct5EV5MtdWQp9iXUA

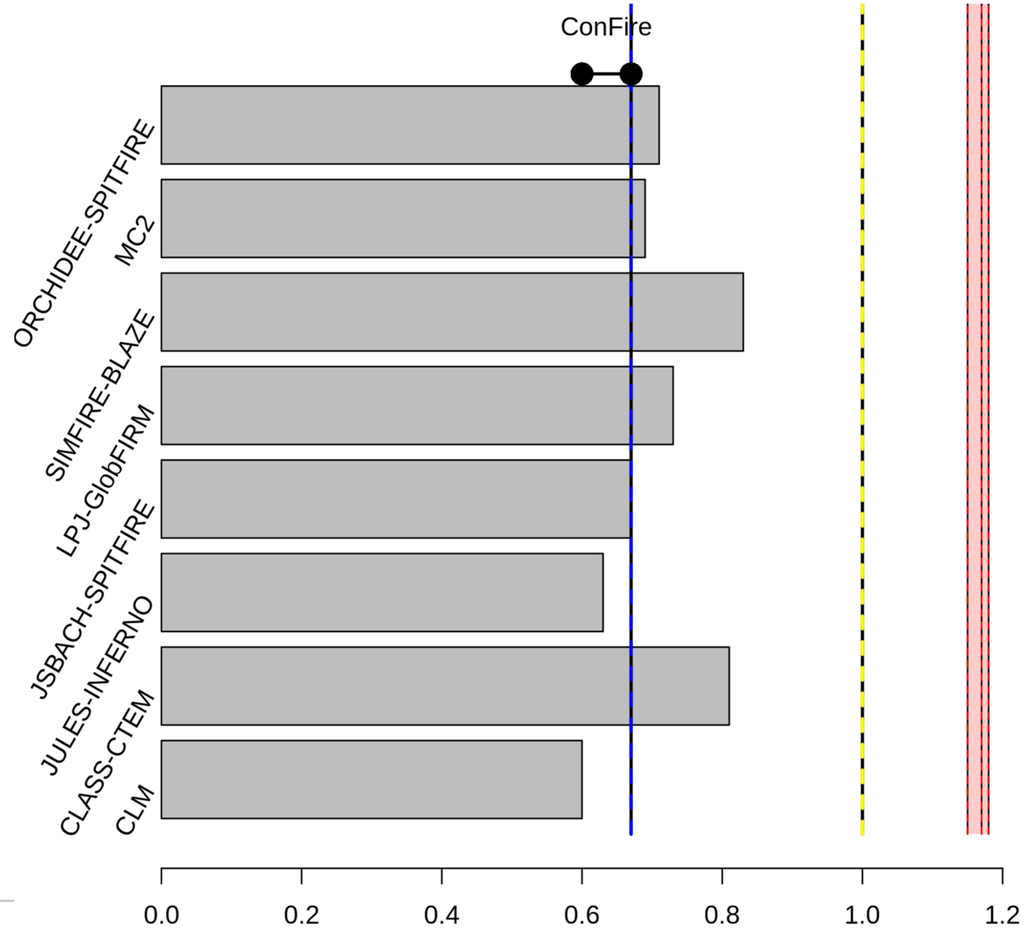
Jamboards

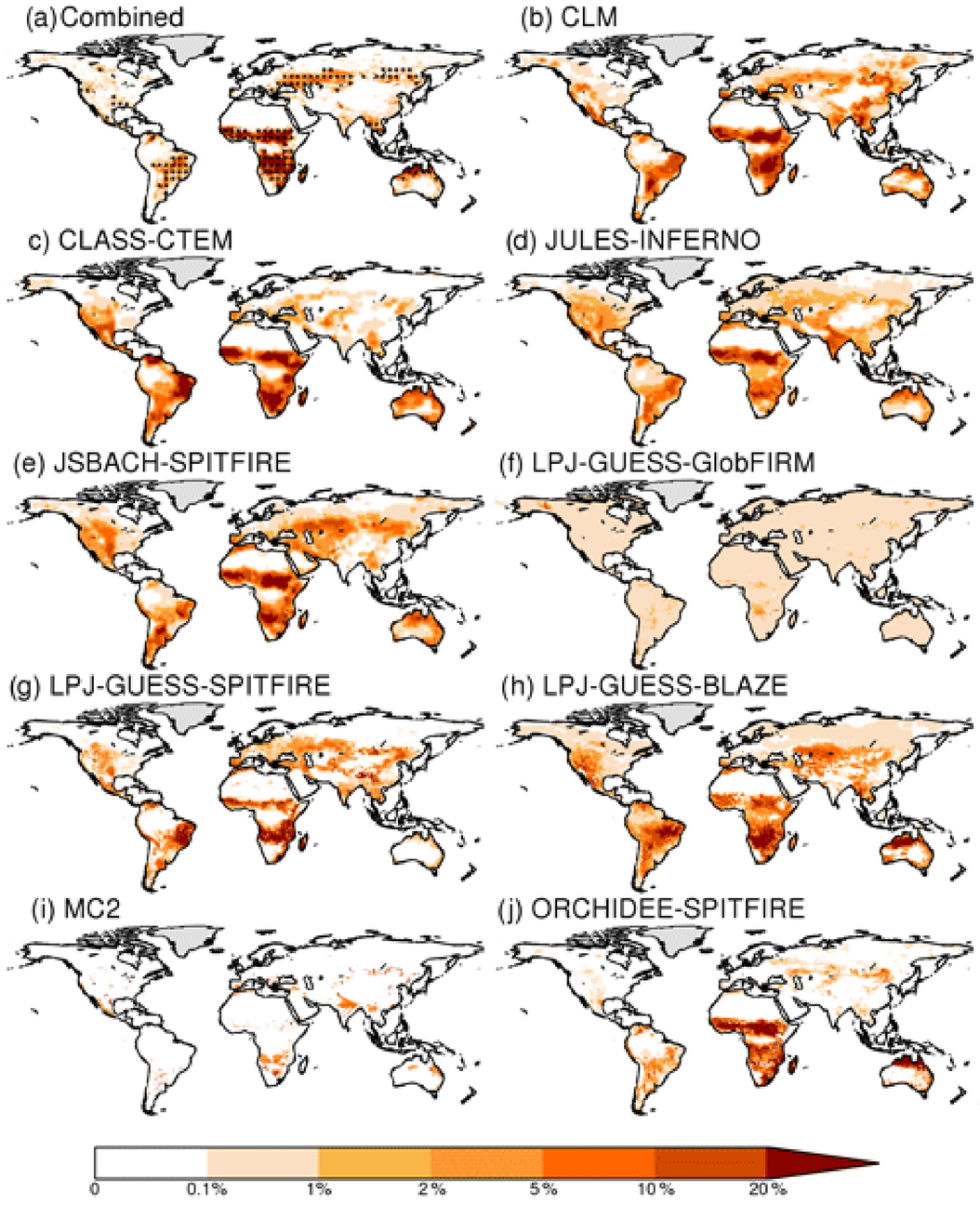
https://jamboard.google.com/d/1airwbvhyAzmlGsSKNEPBFUKUQ-mZwQsllnztfDlkiIw/edit?usp=sharing

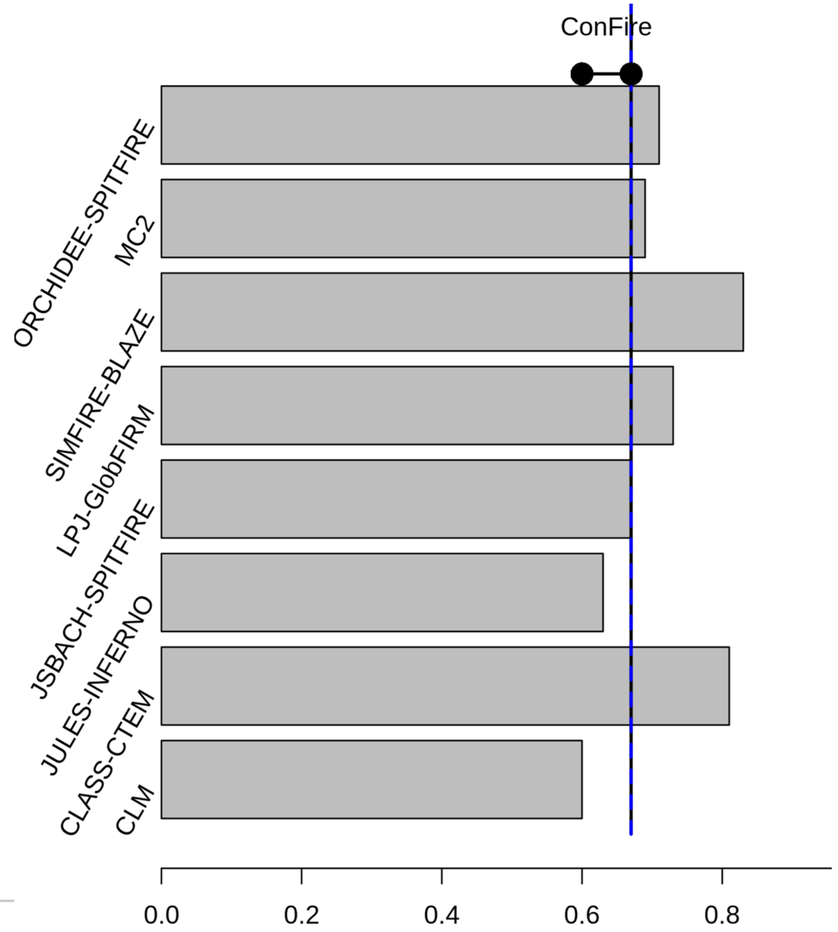
Thanks!

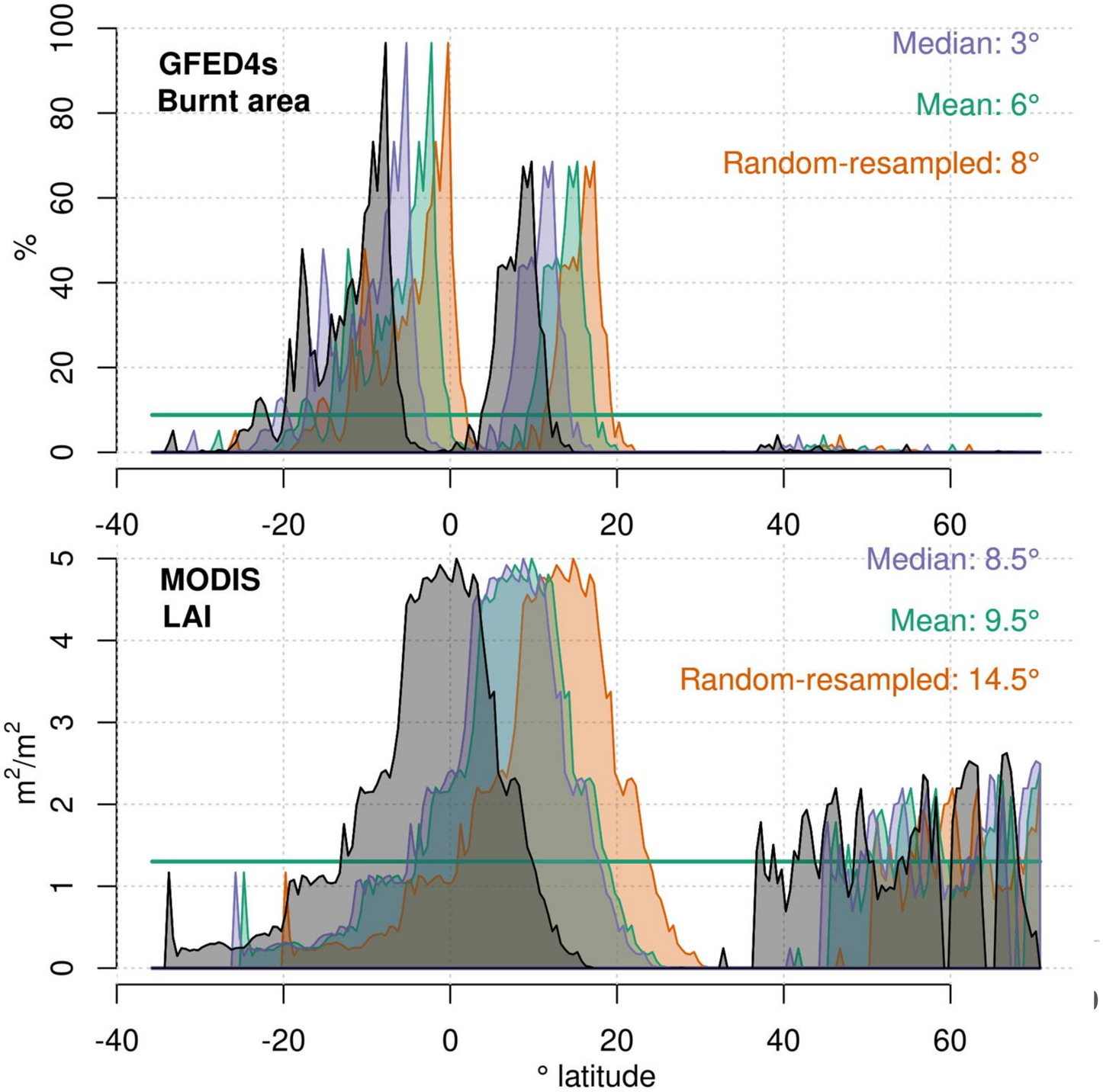
Any questions?




ConFire
ORCHIDEE-SPITFIRE
MC2
SIMFIRE-BLAZE
LPJ-GlobFIRM
JSBACH-SPITFIRE
JULES-INFERNO
CLASS-CTEM
CLM
0.0
0.2
0.4
0.6
0.8
1.0
1.2


(a) Combined
(b) CLM
c) CLASS-CTEM
(d) JULES-INFERNO
(e) JSBACH-SPITFIRE
(f) LPJ-GUESS-GlobFIRM
(g) LPJ-GUESS-SPITFIRE
(h) LPJ-GUESS-BLAZE
(i) MC2
(j) ORCHIDEE-SPITFIRE
0
0.1%
1%
2%
5%
10%
20%





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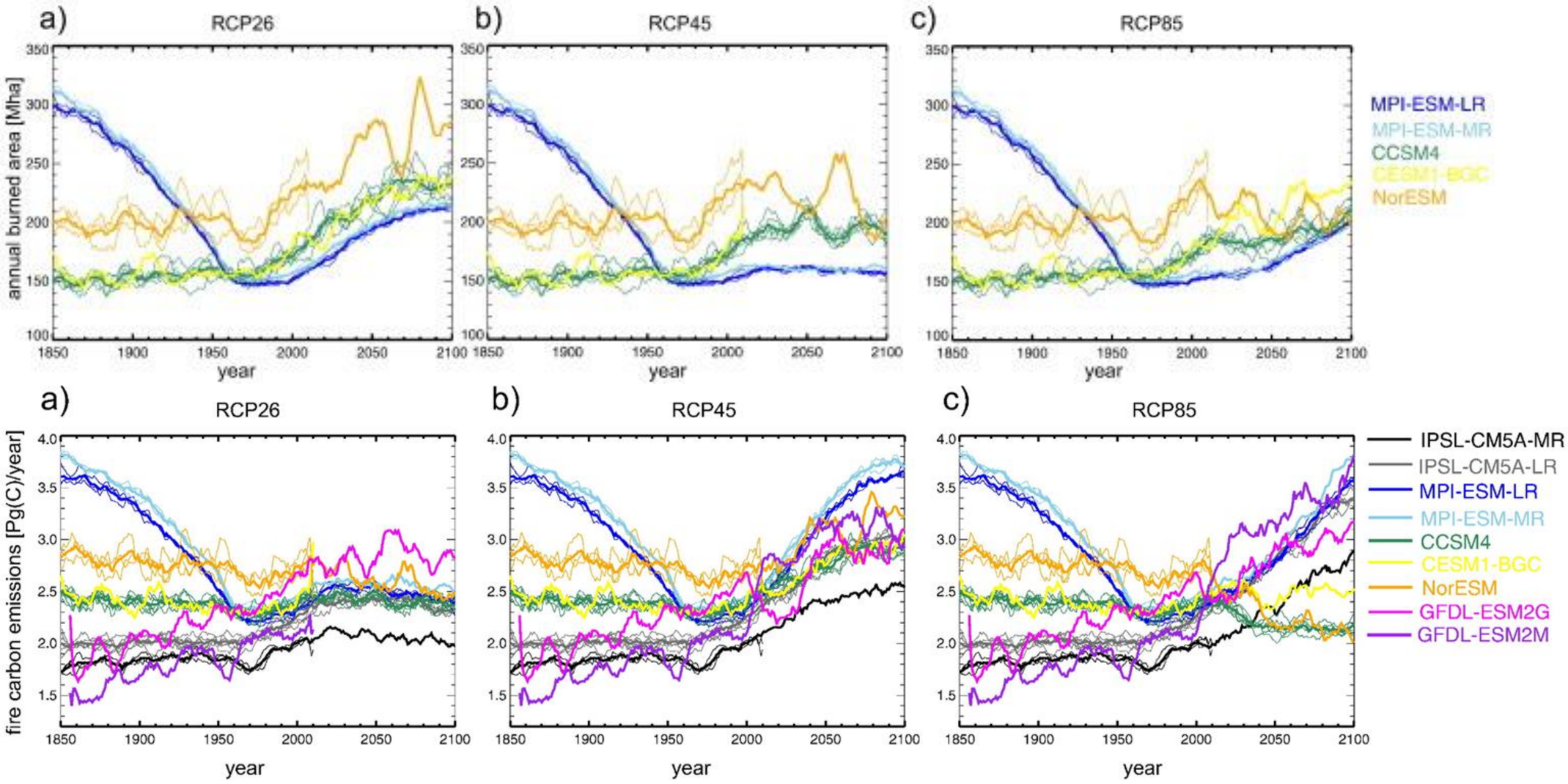
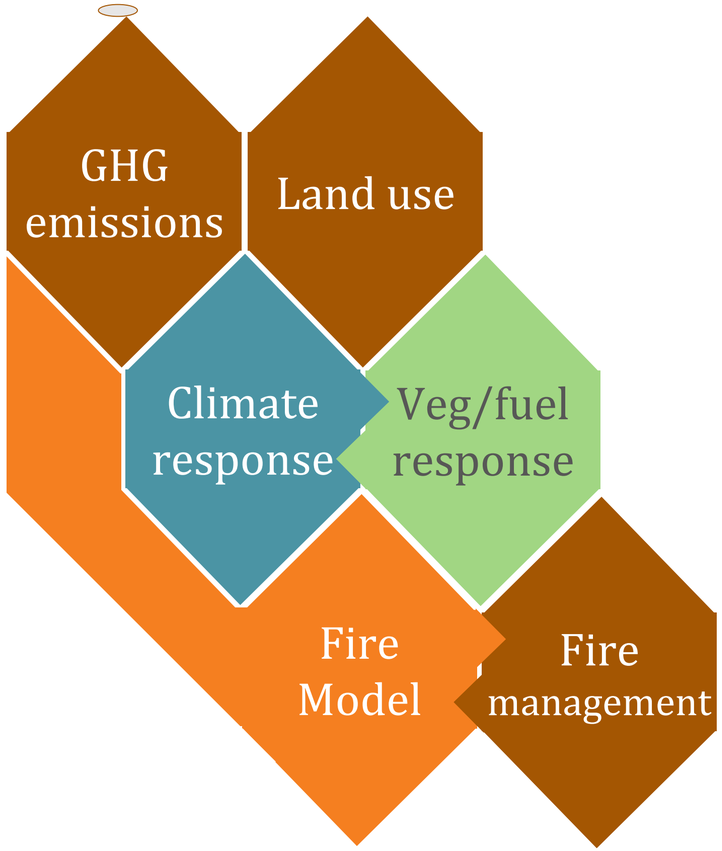
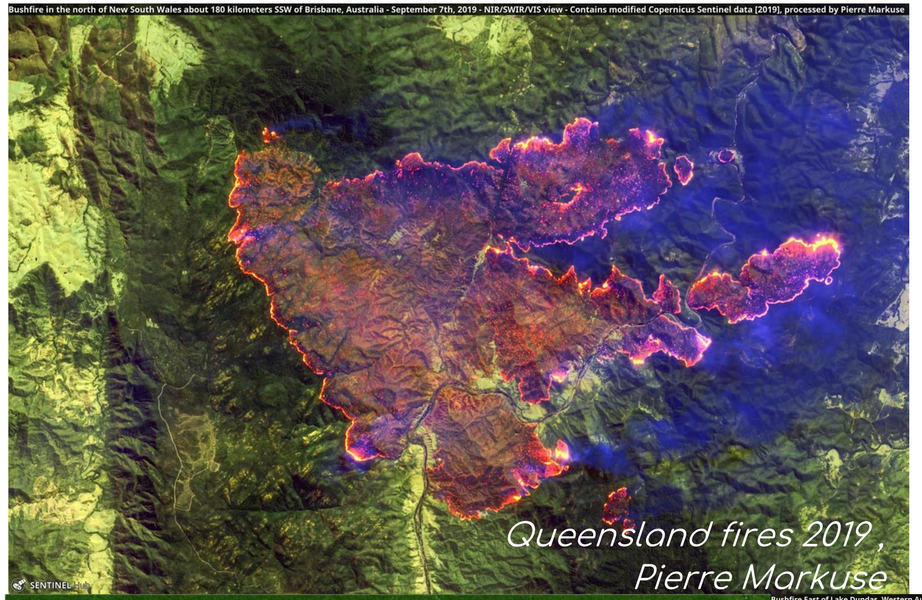
Fire models have some weakness



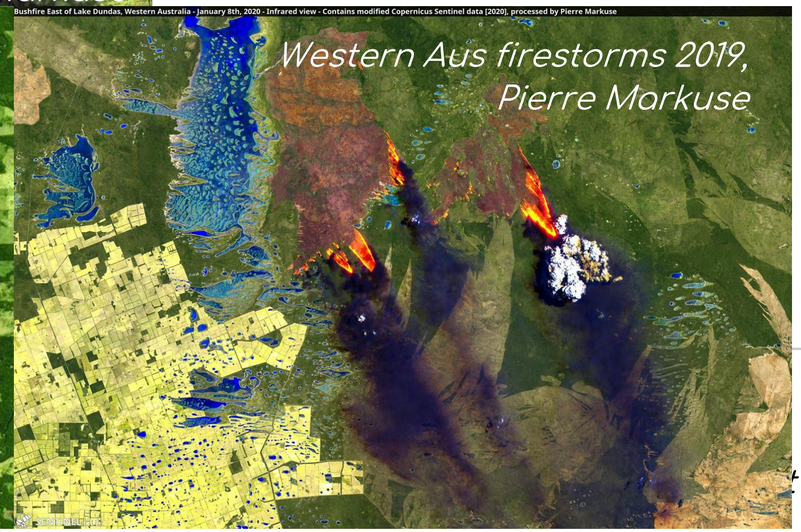
Sources of uncertainty



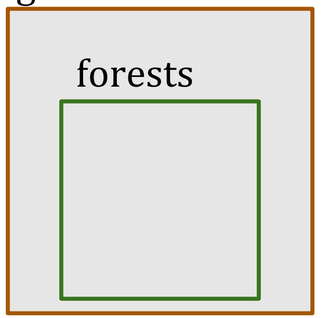


Queensland fires 2019 , Pierre Markuse

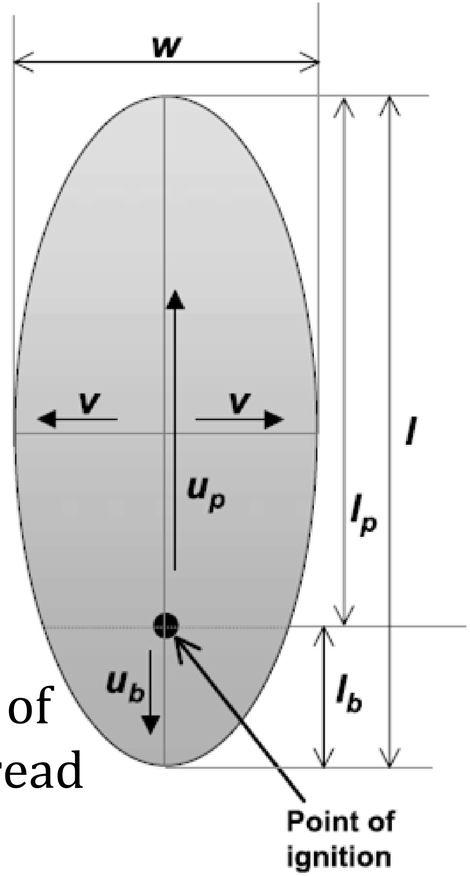
Amazon land clearance 2019, Pierre Markuse



Western Aus firestorms 2019, Pierre Markuse



"Simple" fire model



Rate of spread

Observations

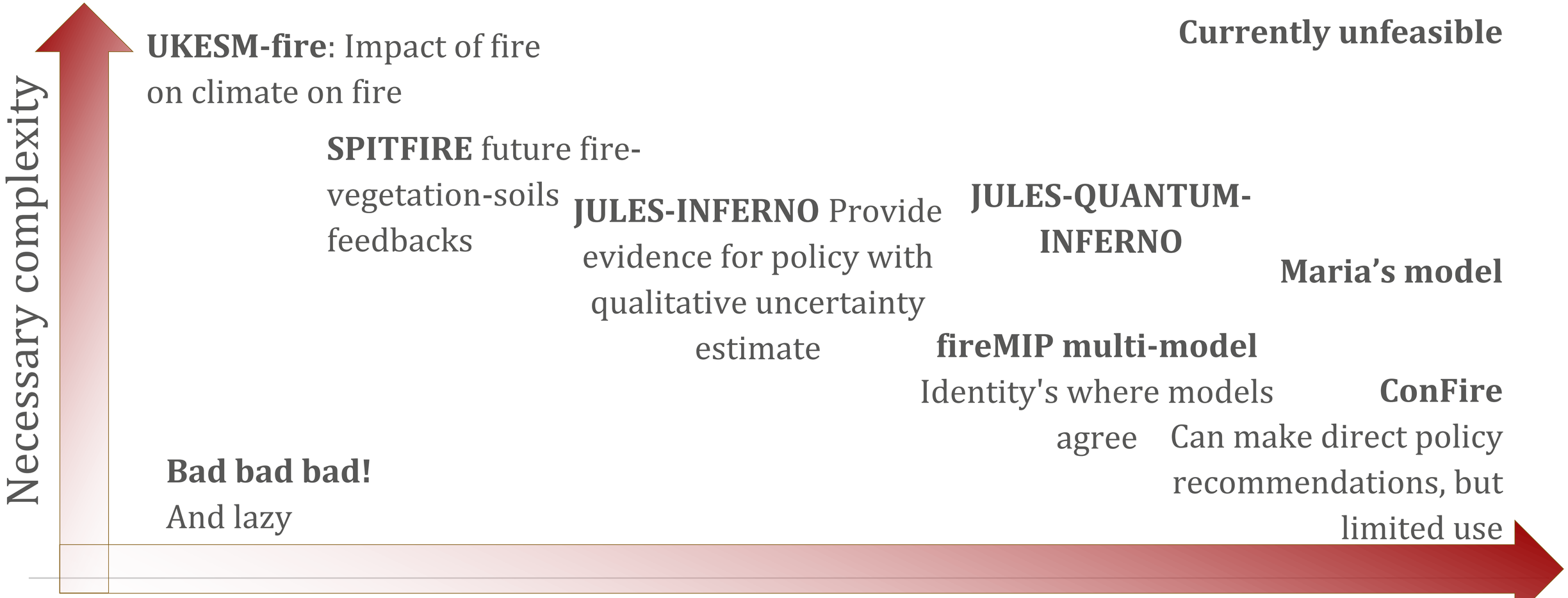
t al 2016

Dummies guide to using fire models

How to define relevant research questions, based on evaluating what the model can do and science/policy/societal needs

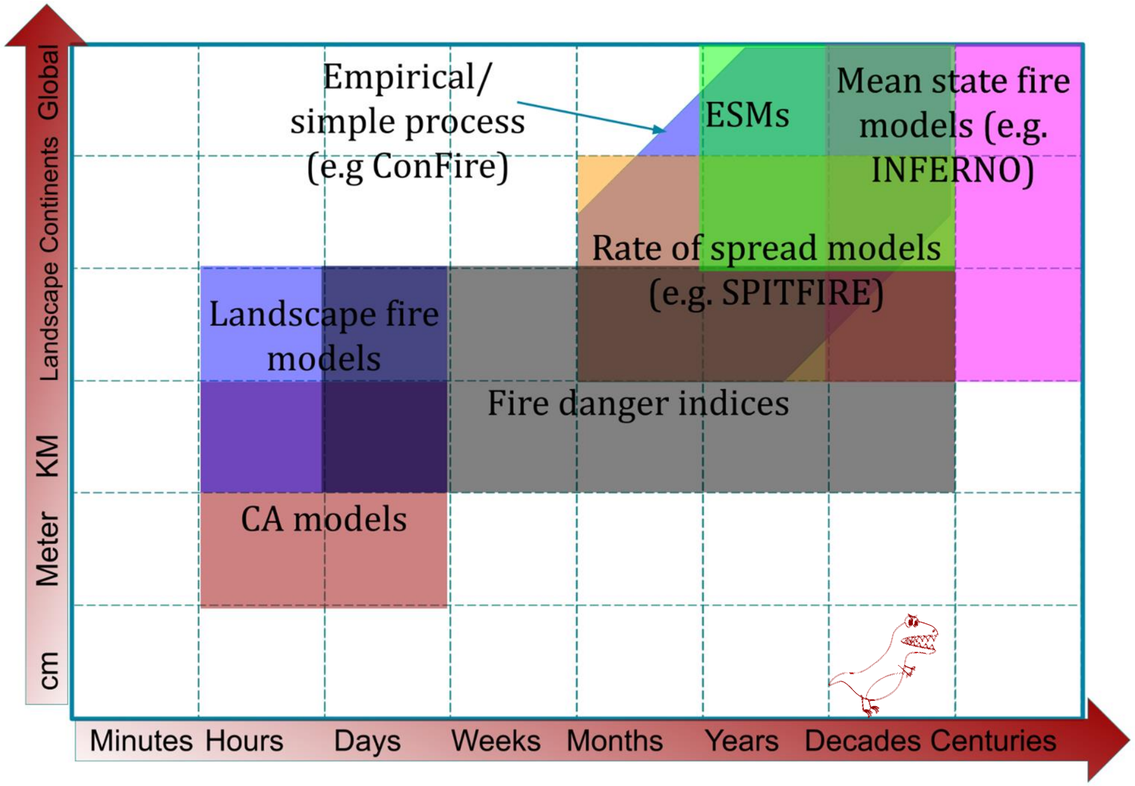
- Necessary complexity
- Causes of uncertainty
- Good practices
  - Characterising model performance
  - Multi-models
  - Quantifying uncertainty
- Need more appropriate metrics
- Identifying useful research question and Social needs of fire models

Using models - Good practices

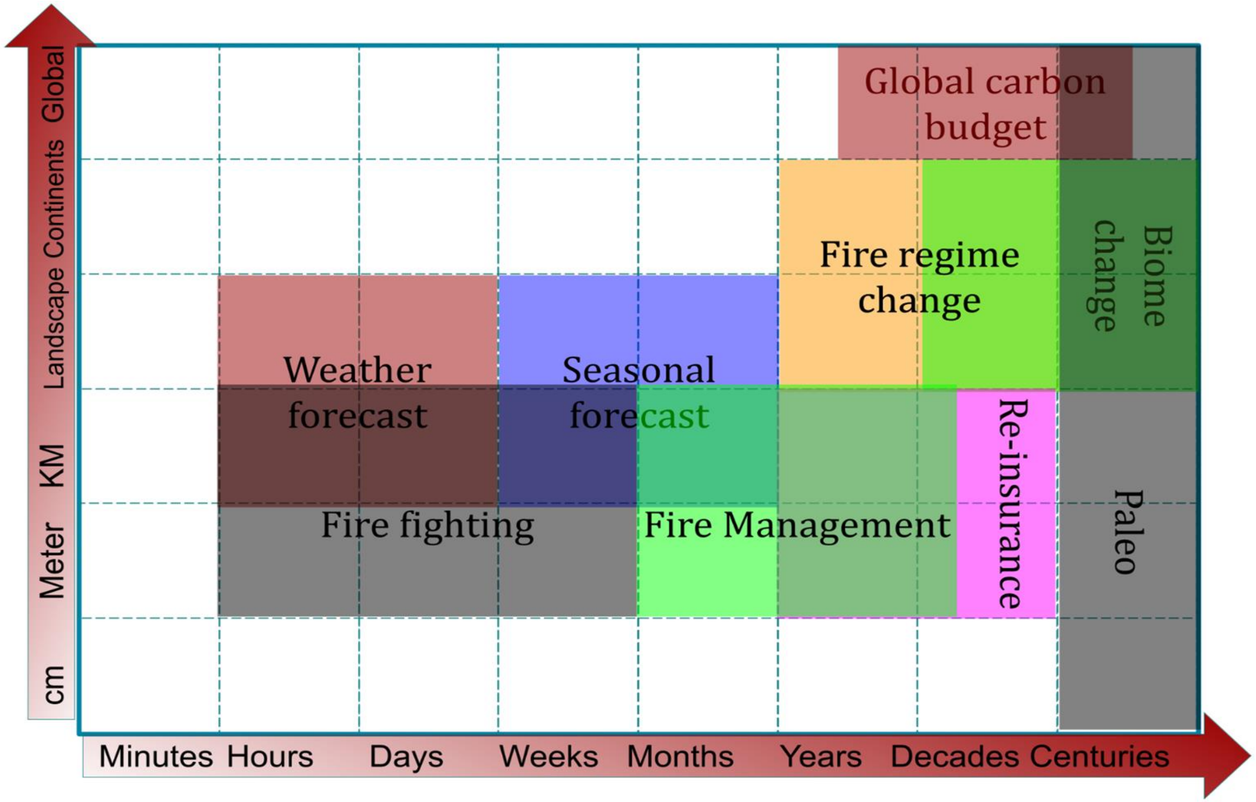


Science and societal needs of fire models

What fire models can “do”



What people need



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Linking fire model evaluation, research questions and societal needs

Identify science, policy and societal needs

Design appropriate research questions

Evaluate and characterise our models

We need your input

- Do you know of any studies with fire model eval informing it's research question(s)?
- Do you have clever ways to assess/account for model uncertainty?
- What would you do differently in hindsight?
- We especially want to hear from you if you're unsure or don't think your research is entirely relevant.

How do you use fire models?

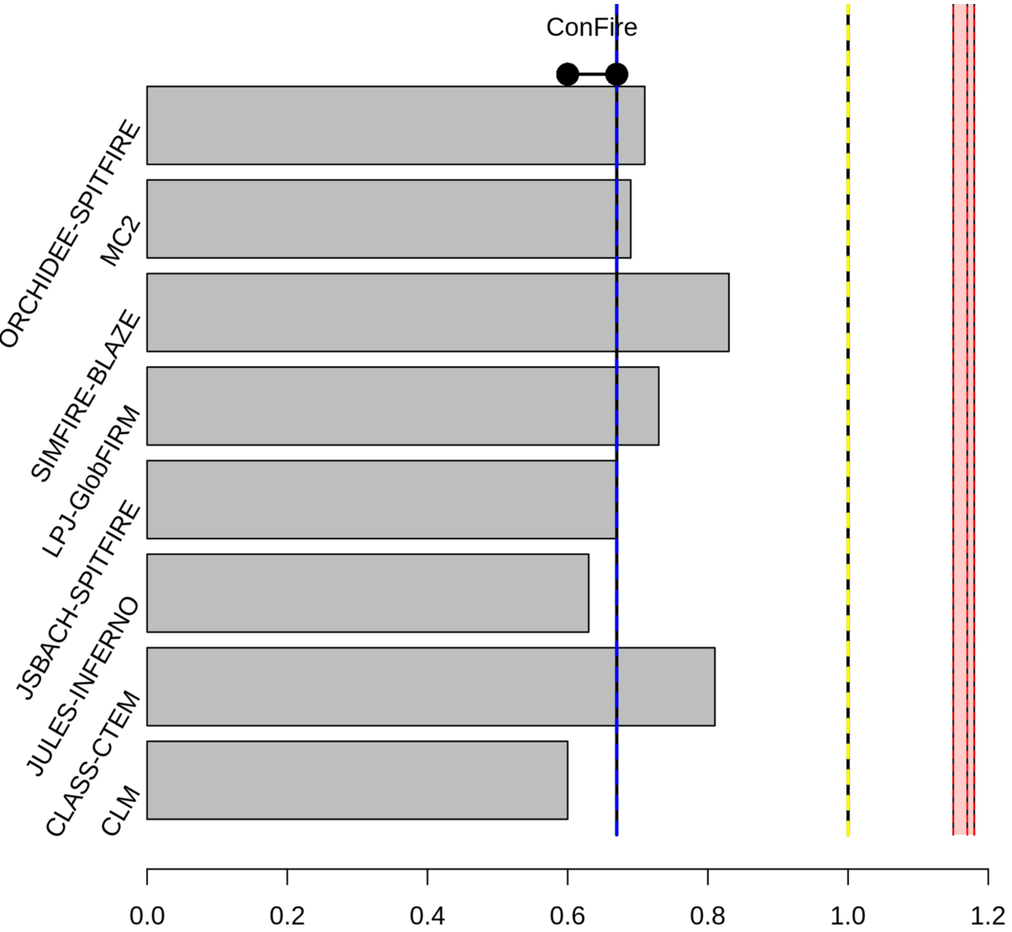
Help us collect good practices for using global fire model outputs

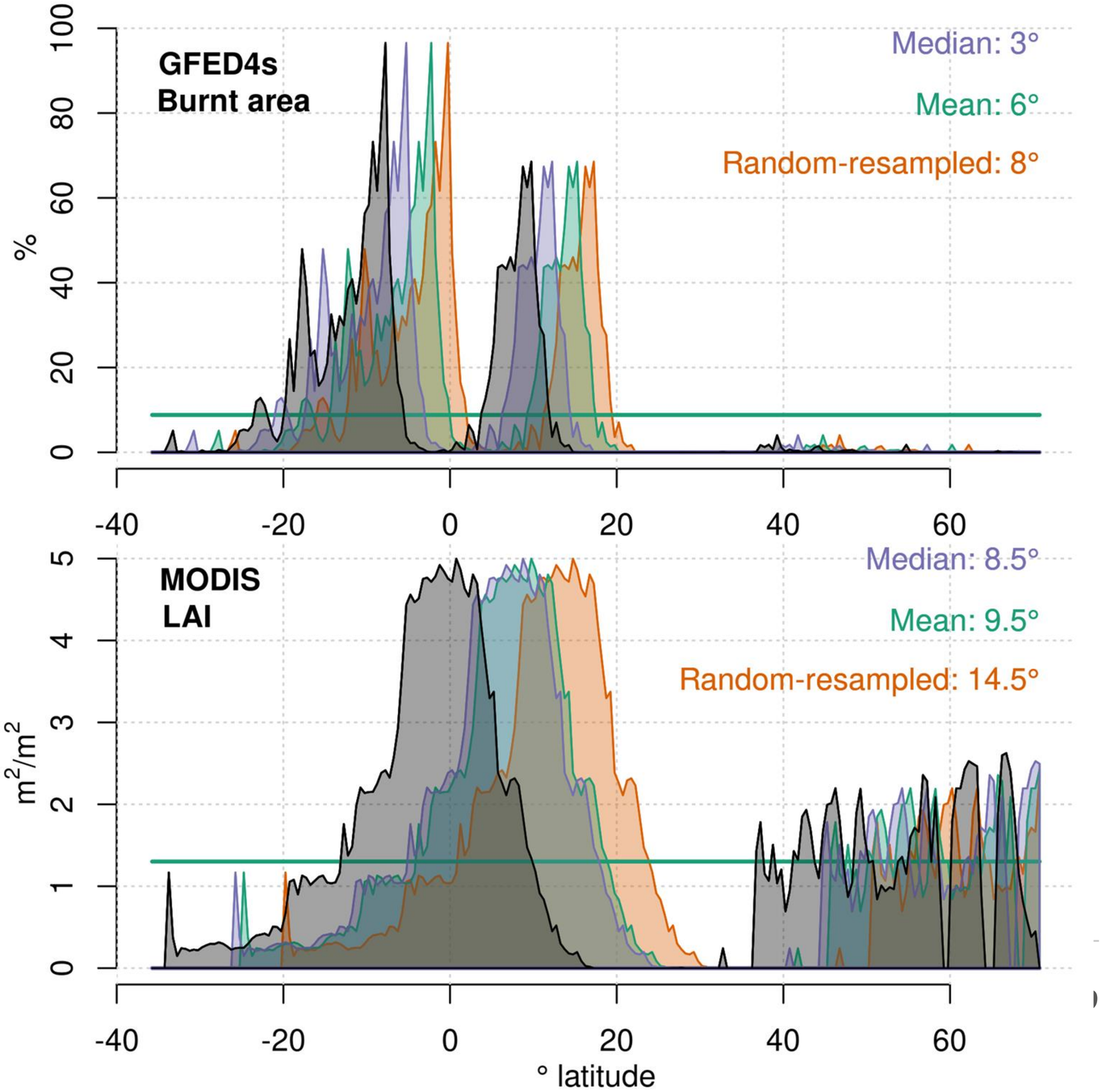
Interview
Doug Kelley
doukel@ceh.ac.uk
Chantelle Burton
chantelle.burton@metoffice.gov.uk
Stacey New
stacey.new@metoffice.gov.uk

Questionnaire by Feb 28
to tell us how you link model evaluation to your research question
https://forms.gle/ct5EV5MtdWQp9iXUA

Anonymous **Jamboards** to capture information about fire models policy relevance
http://bit.ly/3iNSsCS

Spatial Pattern





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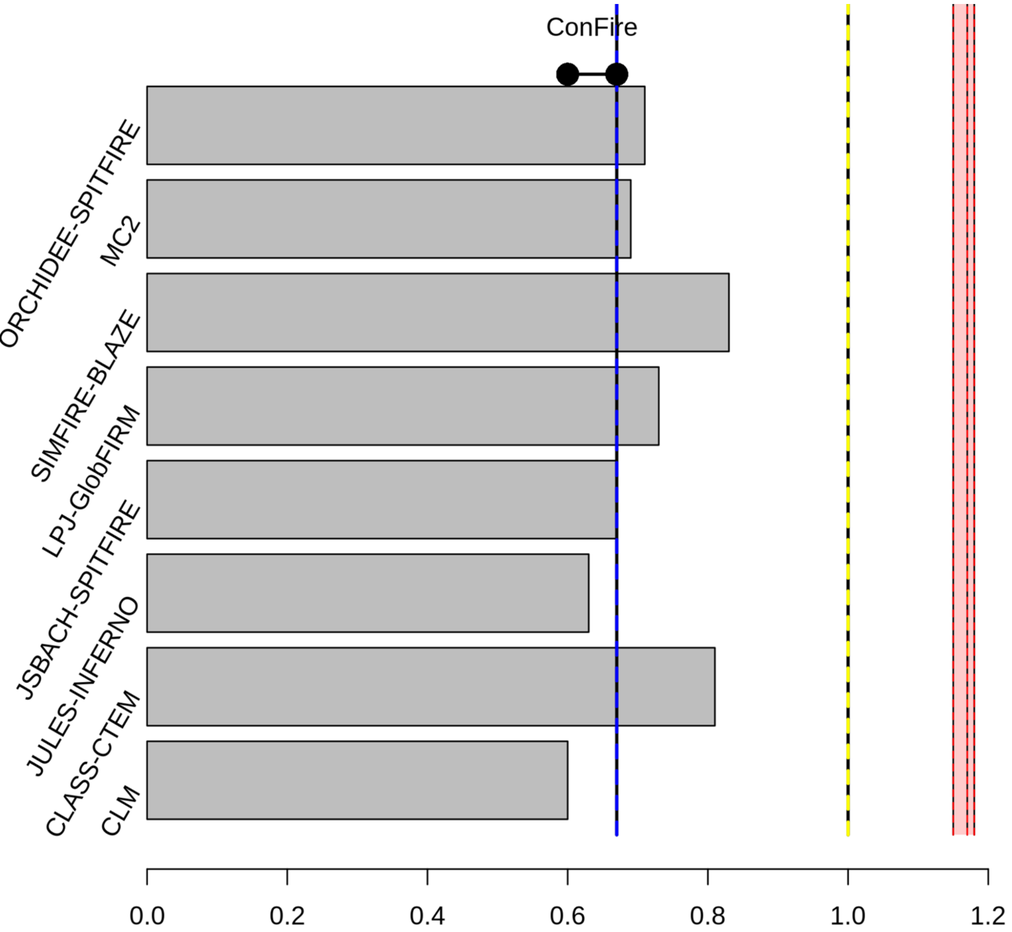
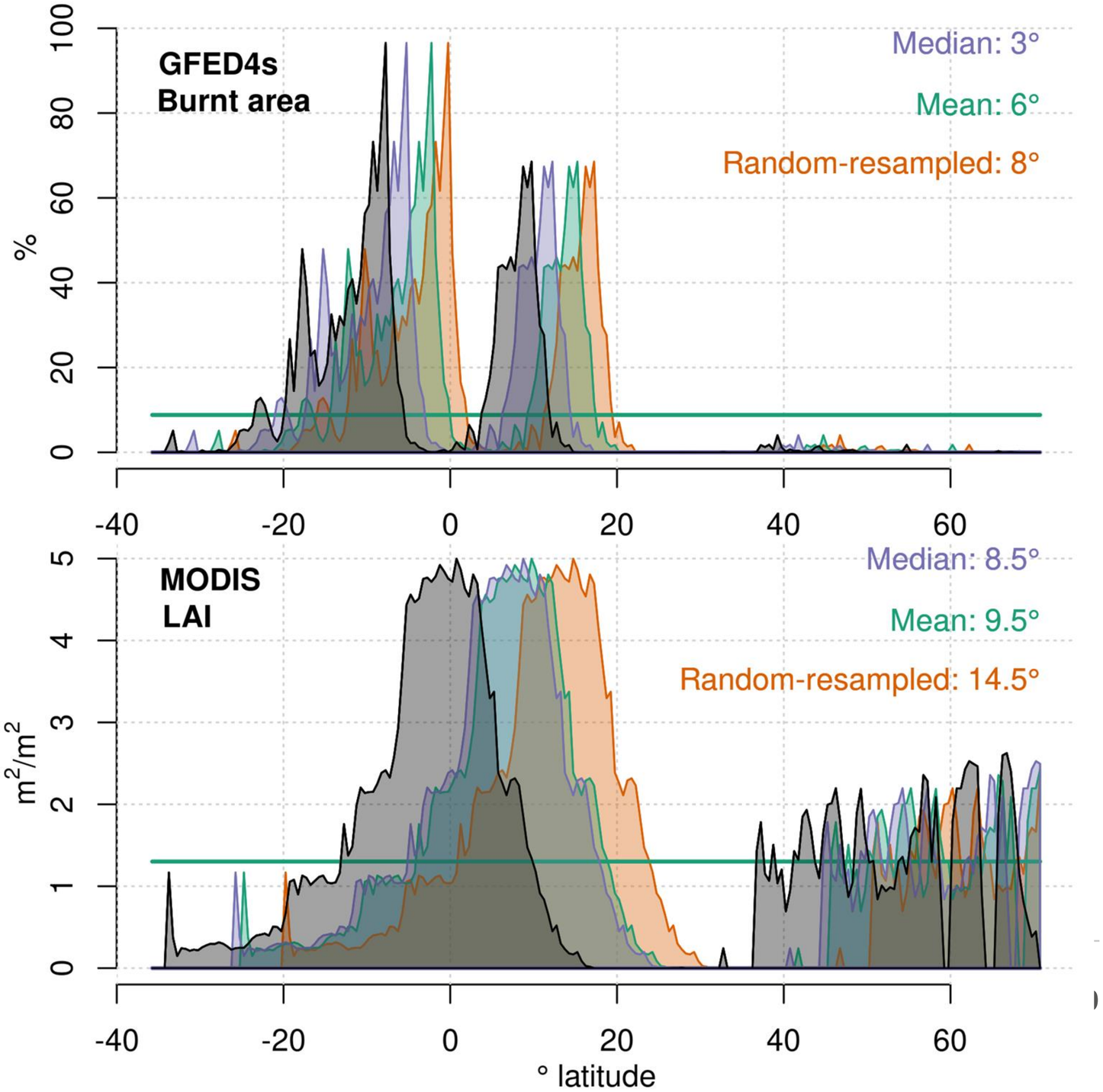
Spatial Pattern





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