



UKESM General Assembly

Science Talks – Session B



David Schroeder

CPOM, University of Reading

Using CryoSat-2 estimates to analyse sub-grid scale sea ice thickness distribution in HadGEM3 simulations for CMIP6



David Schroeder, Danny Feltham

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Michel Tsamados

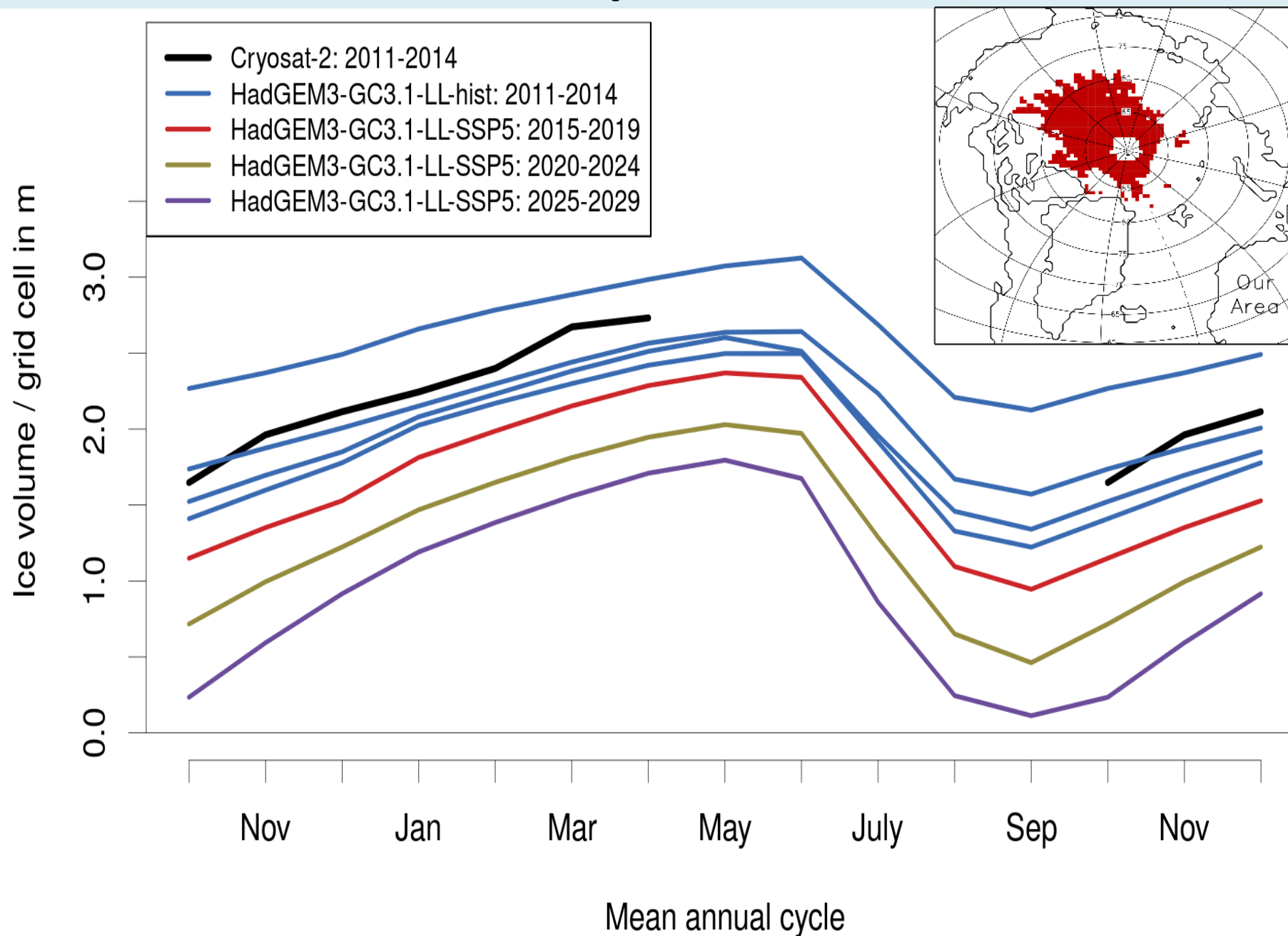
CPOM, Department of Earth Sciences, UCL, UK



Motivation

- A sub-grid scale sea ice thickness distribution (ITD) is a key parameterization to enable a large-scale sea ice model to simulate winter ice growth and sea ice ridging processes realistically.
- Recent sophisticated developments, e.g. a melt pond model, a form drag parameterization, a floe-size distribution model, fundamentally depend on the ITD.
- In spite of its importance, knowledge is poor about the accuracy of the simulated ITD.

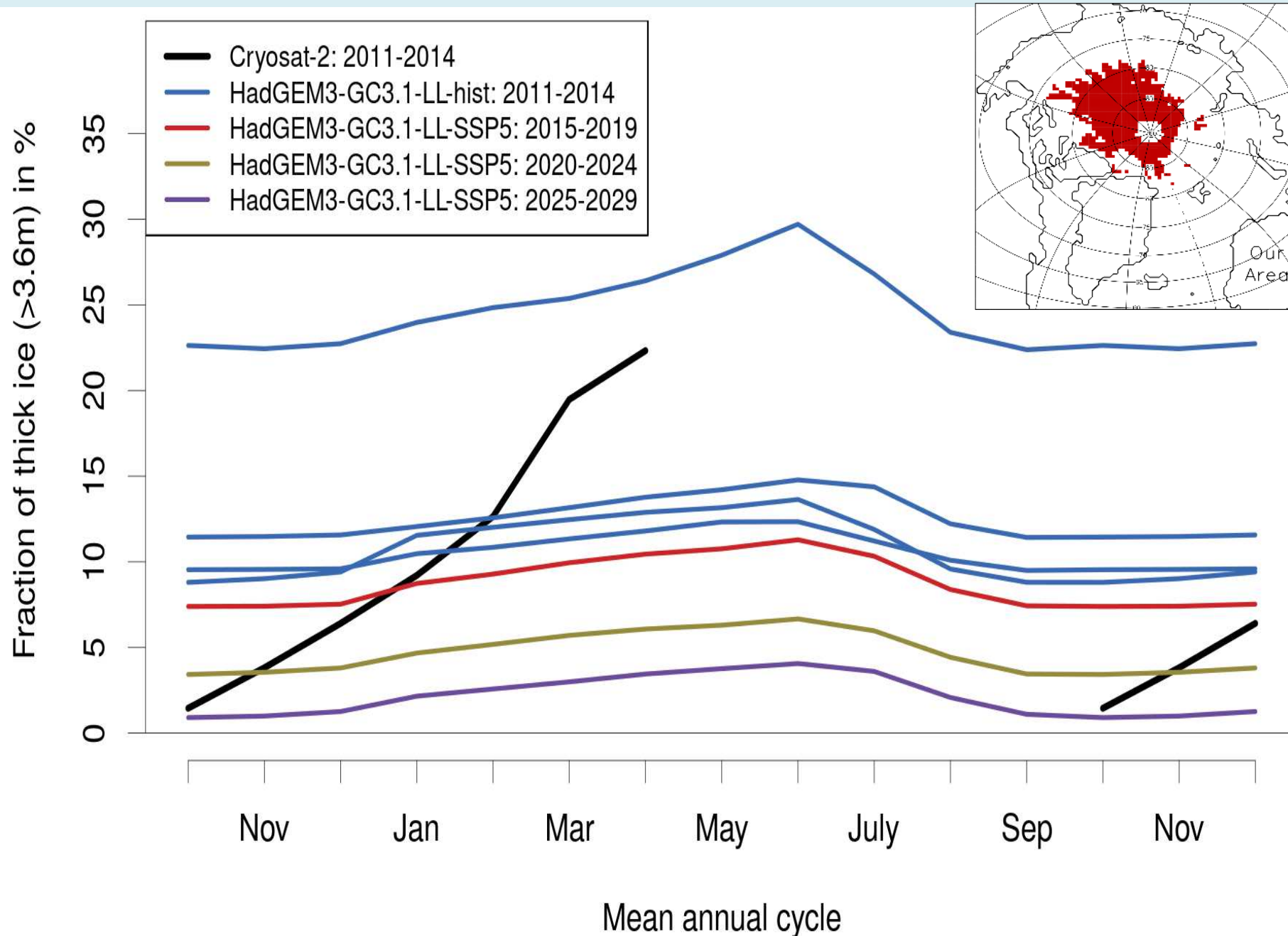
Comparison of ice volume



> 4 ensemble member from historical run (blue lines) represent annual cycle of mean ice volume (2011 to 2014) realistically.

> Strong decrease in climate projection with mean September sea ice thickness down to 10cm in September in the period 2025 to 2029.

Comparison of thick ice area fraction ($h > 3.6\text{m}$)

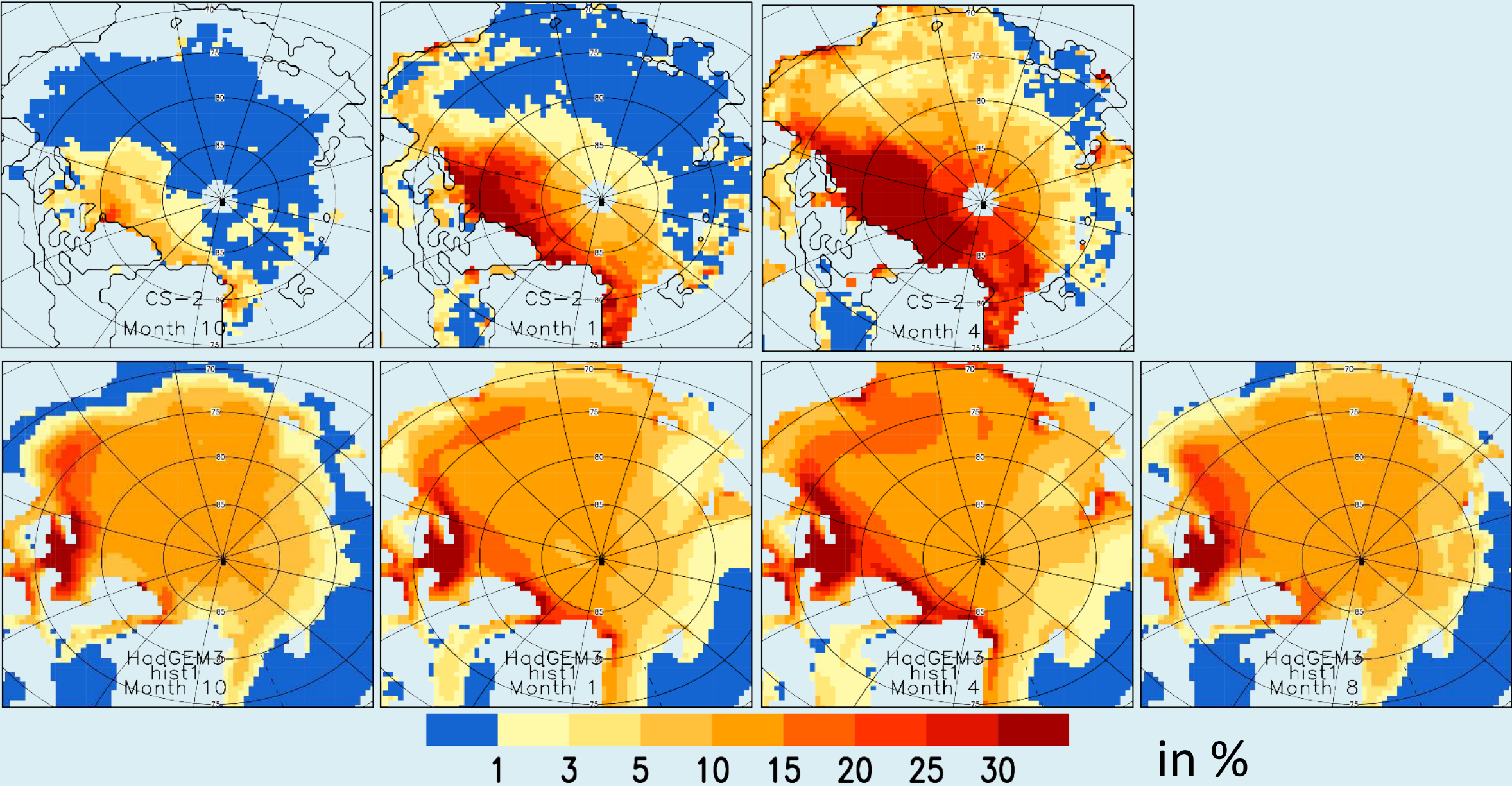


> Strong annual cycle according to CS-2: 2% in October vs 22% in April.

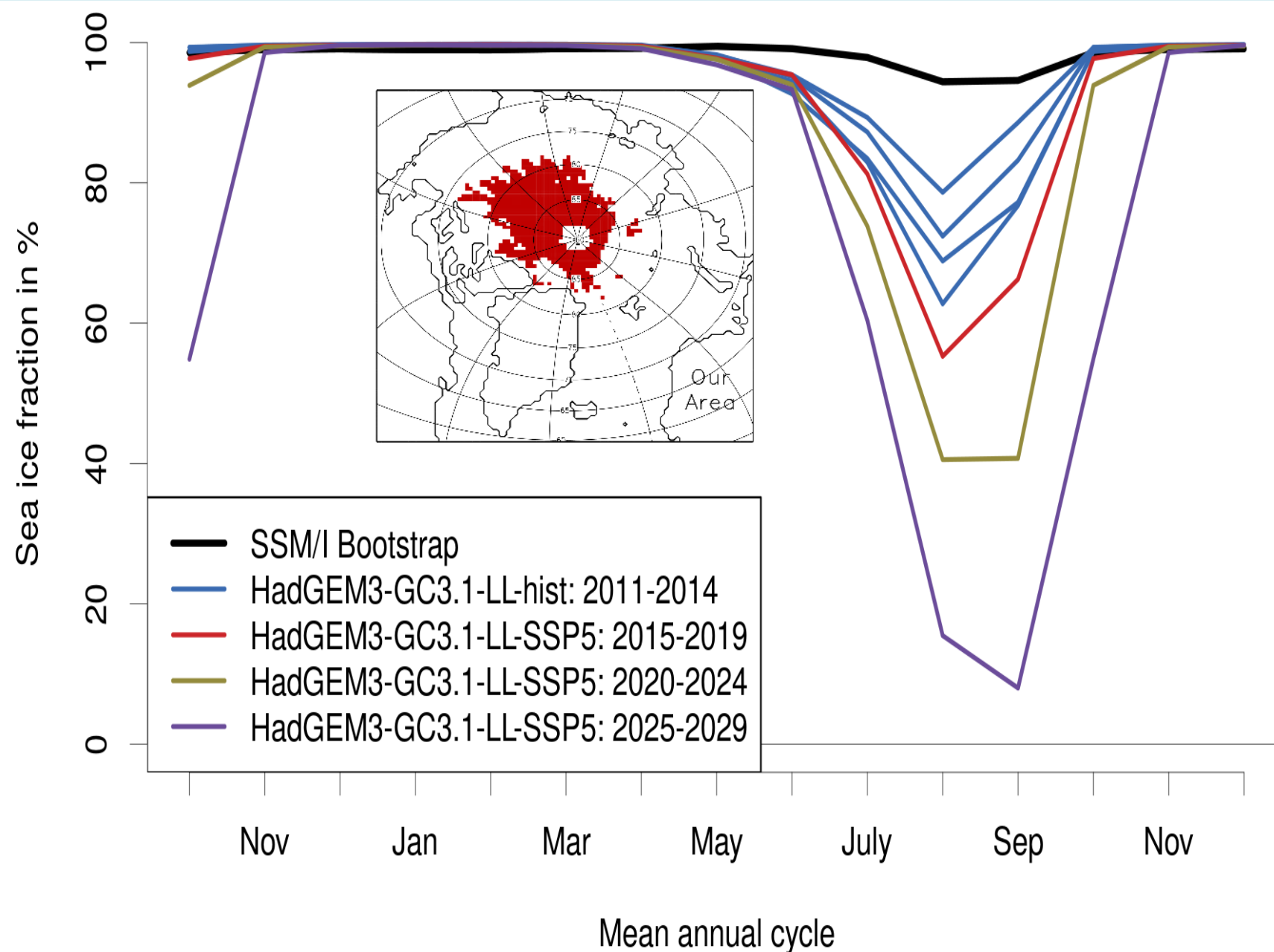
> Weak annual cycle in all HadGEM3 simulations.

> **Should we care about the mismatch given mean ice volume seems to be realistic?**

Comparison of thick ice area fraction ($h > 3.6\text{m}$) 2011-2014 mean



Comparison of ice area fraction



> HadGEM3 underestimates summer sea ice area fraction.

> While thick ice melts too slowly, thin ice melts too fast.

Conclusions

HadGEM3 simulations do not represent annual cycle of thick ice, nor do forced ocean-ice or CICE simulations.



Robin Smith

NCAS, University of Reading

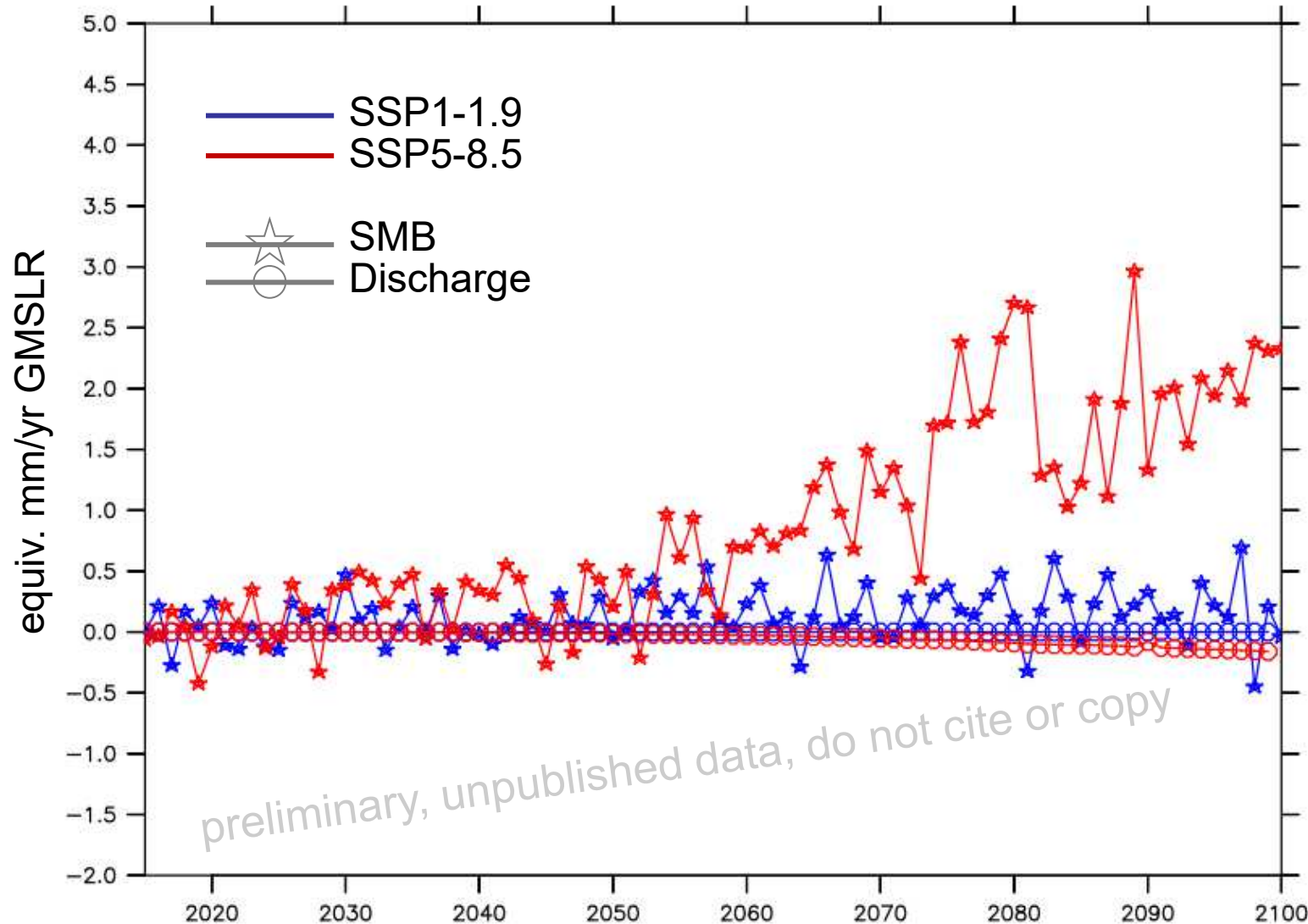
Future contributions to sea-level rise from interactive ice sheets in UKESM1

Robin S. Smith, Victoria Lee, Antony Siahaan, Jonathan Gregory, Paul Holland,
Adrian Jenkins, Tony Payne, Jeff Ridley, Colin Jones and the UKESM core team

preliminary, unpublished data, do not cite or copy

Greenland to 2100...

Change in rate of ice loss, by mass balance component



SSP5 calving/discharge declines as the ice margin thins

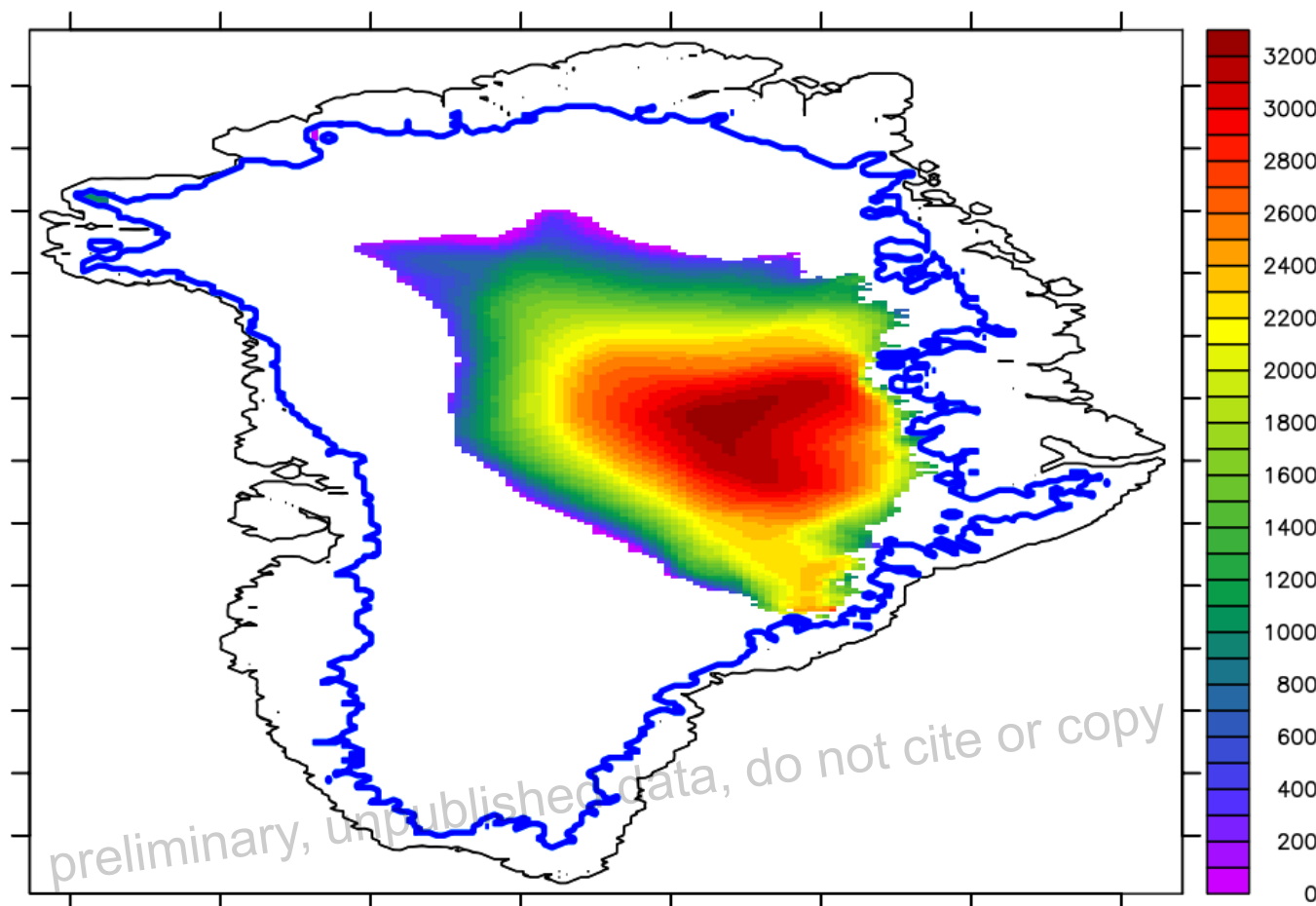
Standalone ISM results see an *increase* in calving: we need marine coupling

Overall response dominated by SMB

New CMIP6 RCM results have higher SMB sensitivity...?

...and beyond!

Ice sheet surface height ~ 3600CE



black contour: modern coast
blue contour: original ice extent

For long term futures we don't need to run the rest of the ESM continuously.

5 ice : 1 climate year

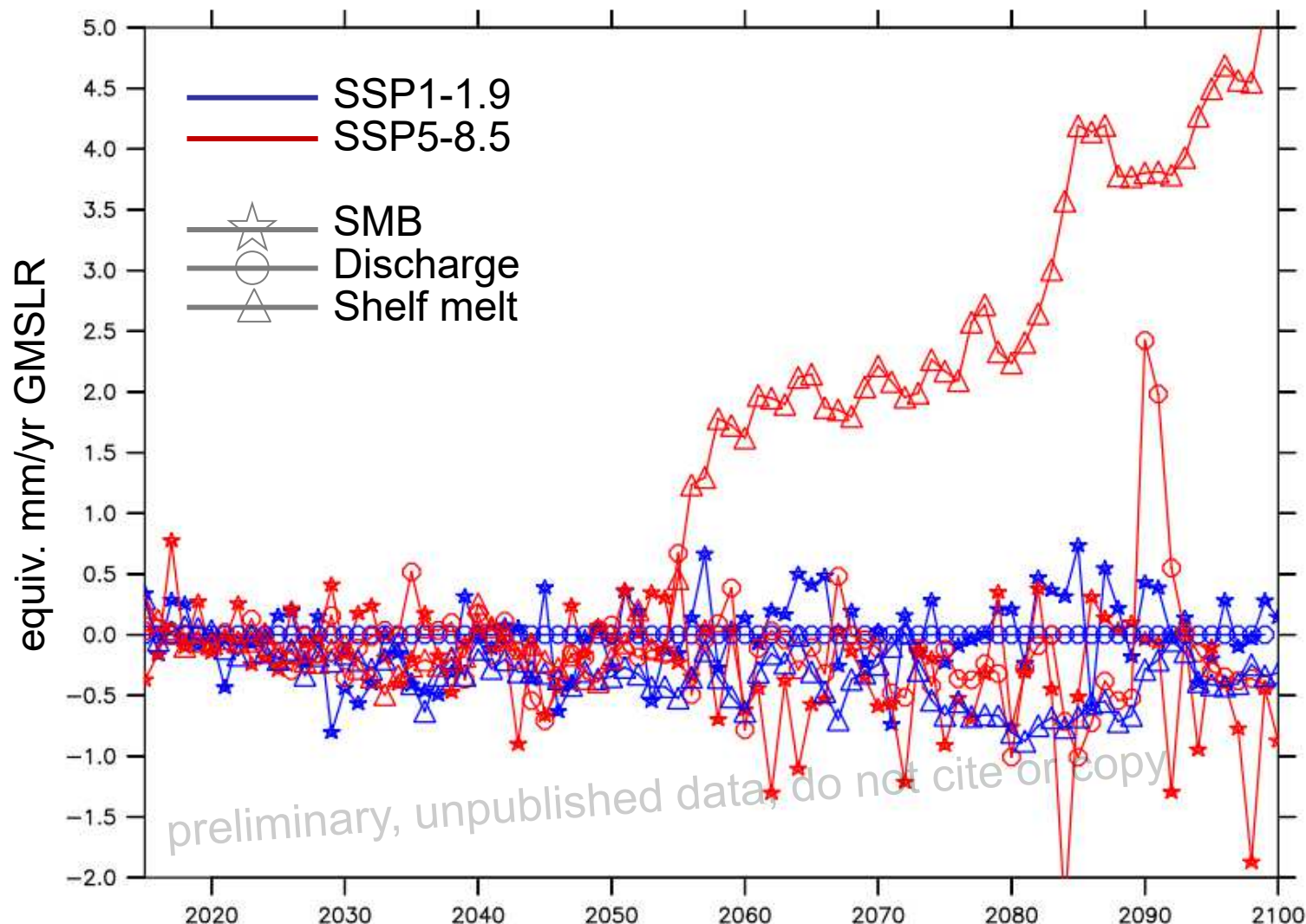
1600 years of ice evolution in a 4xCO₂ climate.

~2/3 of ice mass has been lost.

~5m contribution to GMSL.
Avg SLR rate ~3mm/yr

Antarctica to 2100

Change in rate of ice loss, by mass balance component,



Fair amount of interannual variability

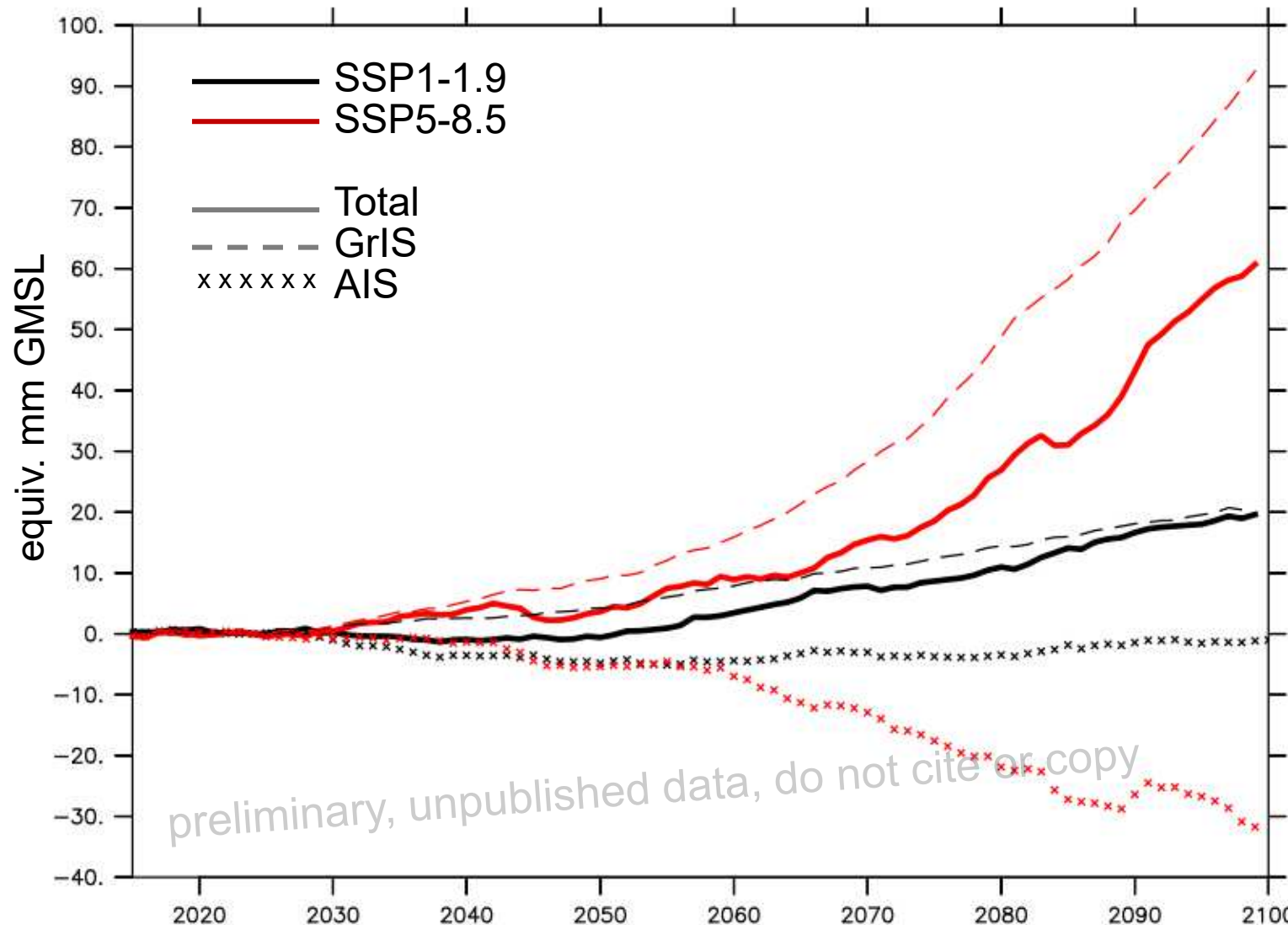
Timing of accelerated shelf melt is sensitive to initial ocean condition

Significant increases in snowfall, especially in SSP5, but widespread melting on shelves

SSP5 discharge hasn't increased. Flow on the shelf slows, but upstream the grounded glaciers are accelerating

Global Mean Sea Level Rise

additional contributions to GMSL



cf global (SROCC)

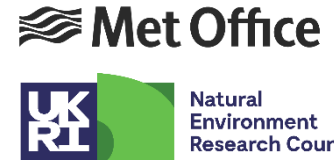
40 to 230mm RCP 2.6

RCP 8.5
100 to 570mm

-70 to 270mm AIS RCP8.5 (ISMIP6)

cf per sheet (ISMIP6)

40 to 140mm GrIS RCP8.5 (ISMIP6)



Loss of ice volume above flotation is crude estimate for now

Ignoring loss of floating mass from shelves, SSP5 Antarctic sees net influence of snowfall accumulation

SSP1 has modest loss of mass from GrIS

Results are within multi-model bounds!

Vicky Lee

CPOM, University of Bristol





University of
BRISTOL

Atmospheric blocking and Greenland melt

Victoria Lee, Centre for Polar Observations and Modelling, University of Bristol

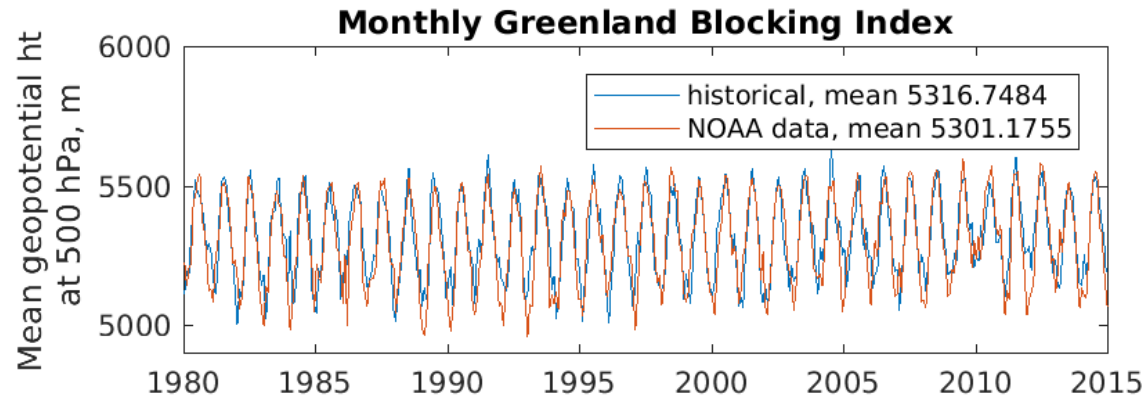
v.lee@bristol.ac.uk

Robin S. Smith, NCAS-Climate, University of Reading

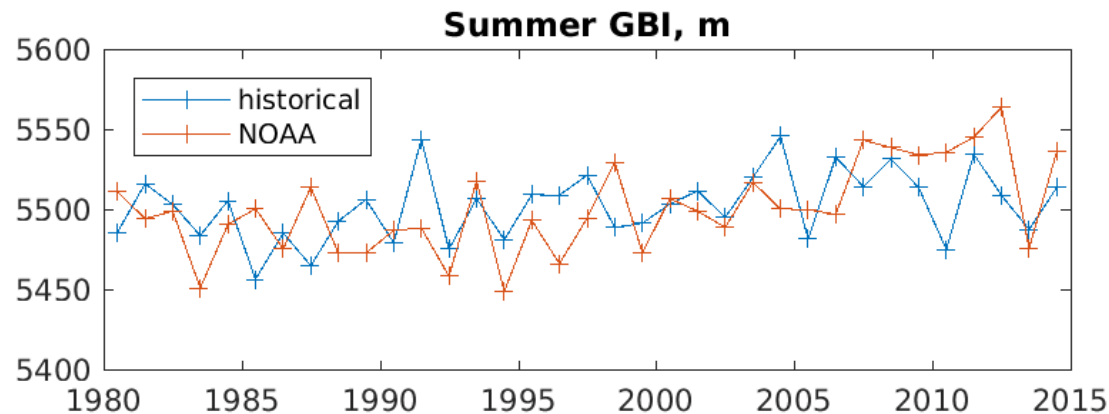
Tony Payne, CPOM, University of Bristol

Greenland Blocking Index (GBI)

- It measures atmospheric blocking over Greenland.
- GBI is the mean 500 hPa geopotential height for the 60-80°N, 20-80°W region.
- A comparison of monthly means between **UKESM1.ice 1970-2014 historical experiment** with NCAR/NCEP Reanalysis from NOAA is good.
- Summer, JJA, GBI: historical model matches mean but has a smaller std.
- Reanalysis has a positive trend in summer GBI from 1995, whereas CMIP5 models do not.



RMSE is 83 m

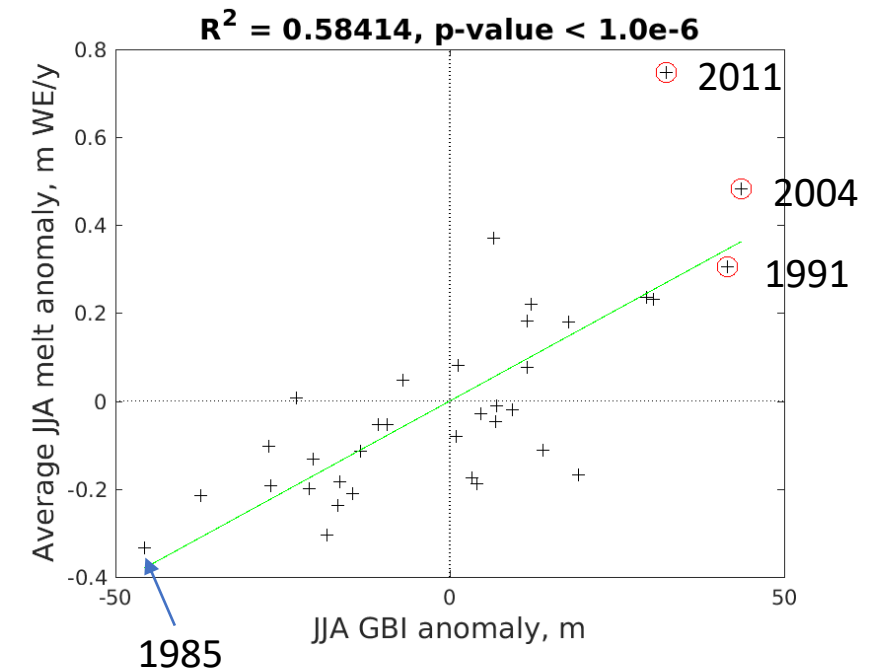
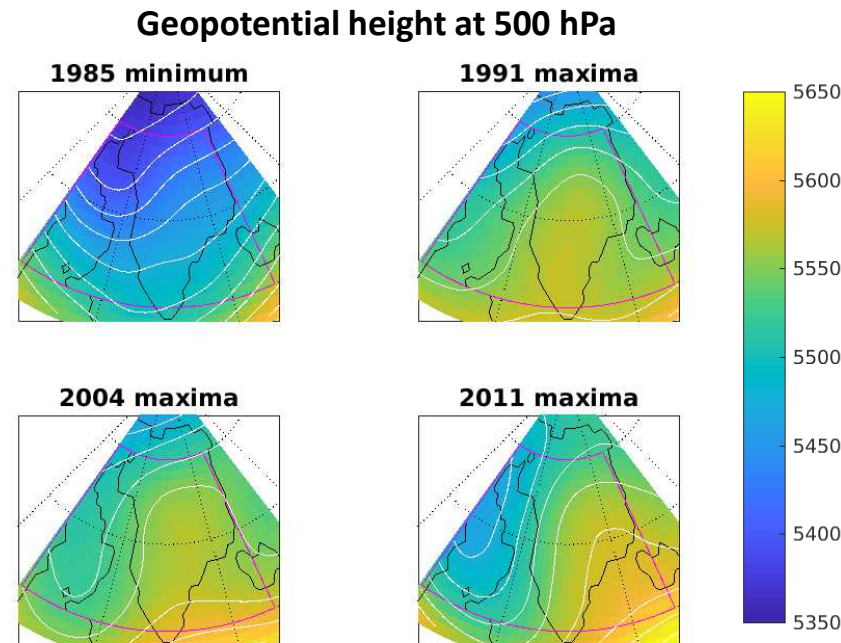
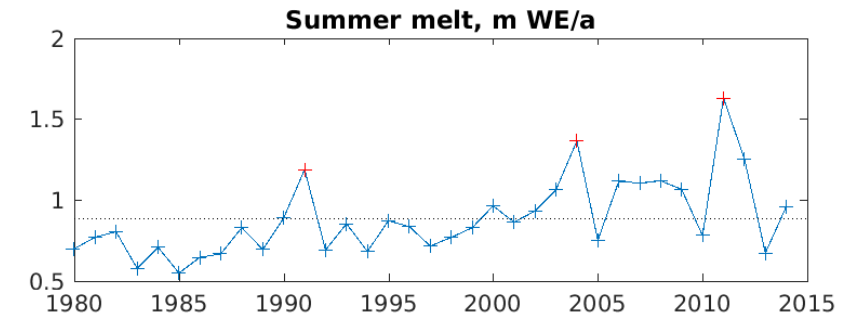
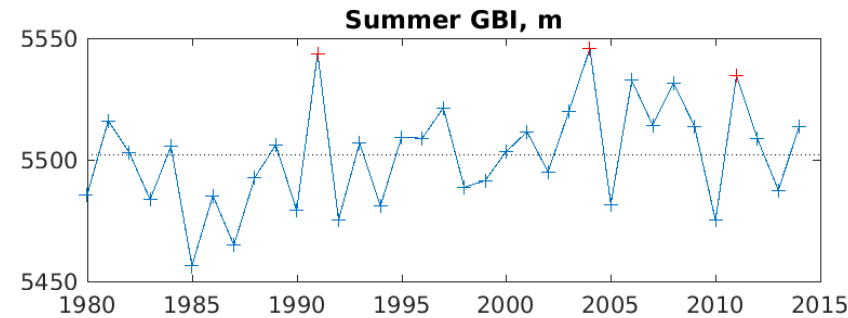


Historical:
 $\mu = 5502$ m, $\sigma = 21.6$ m
Reanalysis:
 $\mu = 5501$ m, $\sigma = 28.2$ m

RMSE is 29 m

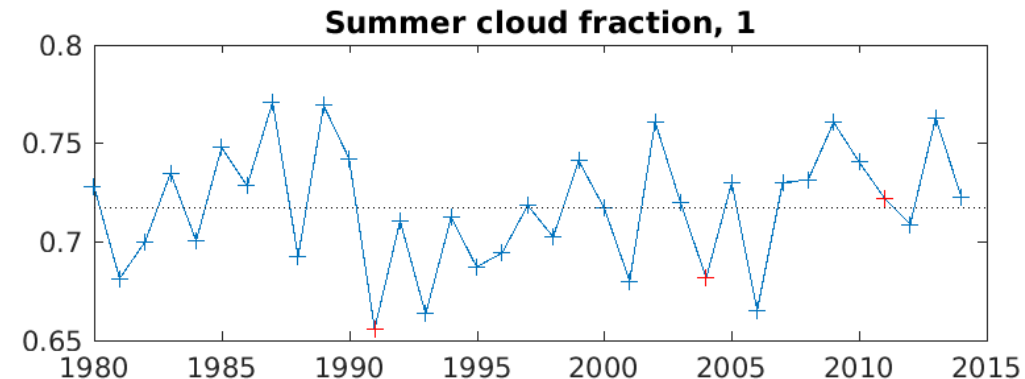
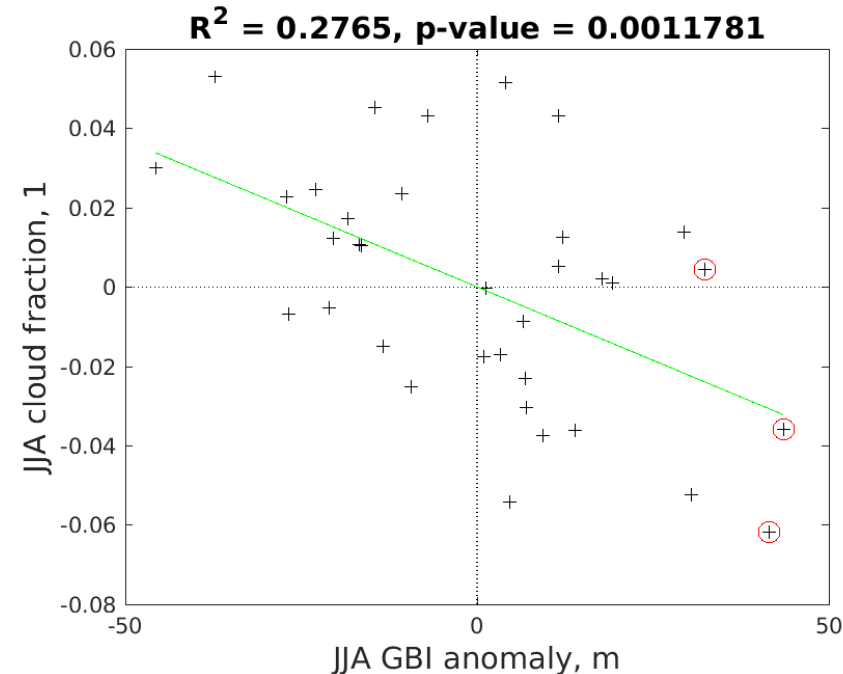
GBI and Greenland melt in UKESM1.ice historical

- Anomalous Greenland blocking has been linked to the recent surface melt acceleration over the Greenland Ice Sheet.
- It can advect relatively warm air masses from the subtropics and bring sunnier and drier weather conditions that enhance the melt.
- In the historical model the top three summer GBI values correspond to maxima in ice sheet melt.
- Summer GBI and ice sheet melt rate are positively correlated.



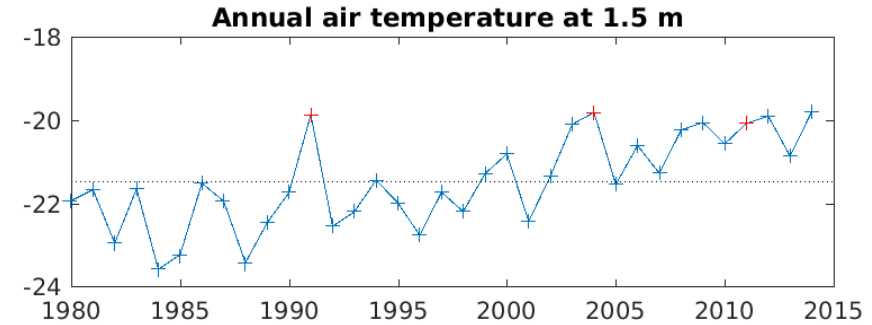
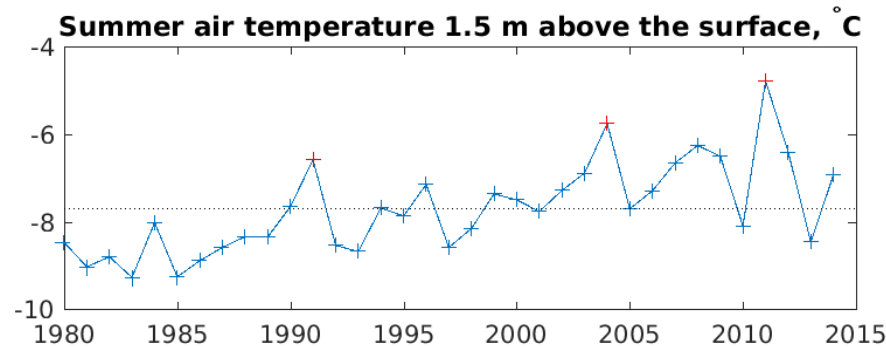
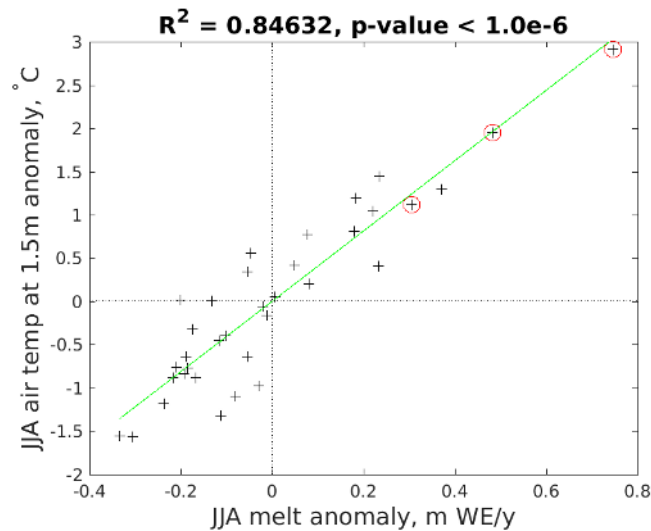
Greenland blocking and cloud cover over GrIS

- Recent literature has found that GBI is negatively correlated to cloud cover since the mid-1990s based on a combination of satellite observations and RCM modelling.
- Blocking is promoting cloud dissipation and the reduction in cloud cover is driving Greenland's recent mass loss.
- In the historical model GBI and cloud fraction are weakly, negatively correlated.
- Positive trend in cloud fraction since 1990 ($R^2 = 0.28$ p -value = 0.008).
- Melt rate and cloud cover do not have a significant correlation.
- Cloud cover has a complex interaction with surface melt.



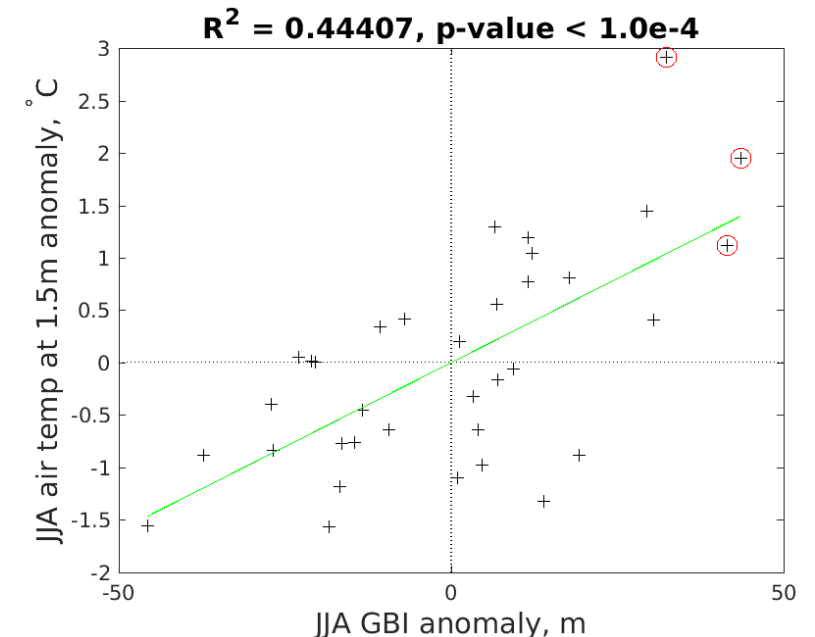
Near-surface air temperature over GrIS

- Blocking can drive advection of warm air.
- In the historical model annual near-surface air temperature is warming at $0.12\text{ }^{\circ}\text{C/y}$ since 1995.



- Maxima in melt rate correspond to maxima in JJA temperature at 1.5 m.
- Melt and JJA temperature at 1.5 m are highly correlated.
- GBI and temperature are not strongly correlated.

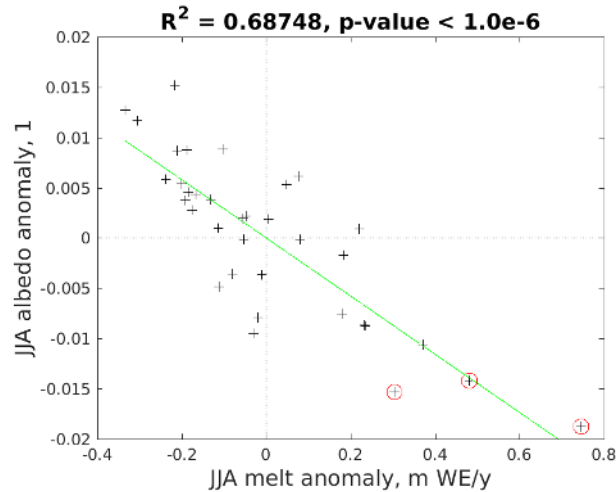
And with GBI



Albedo

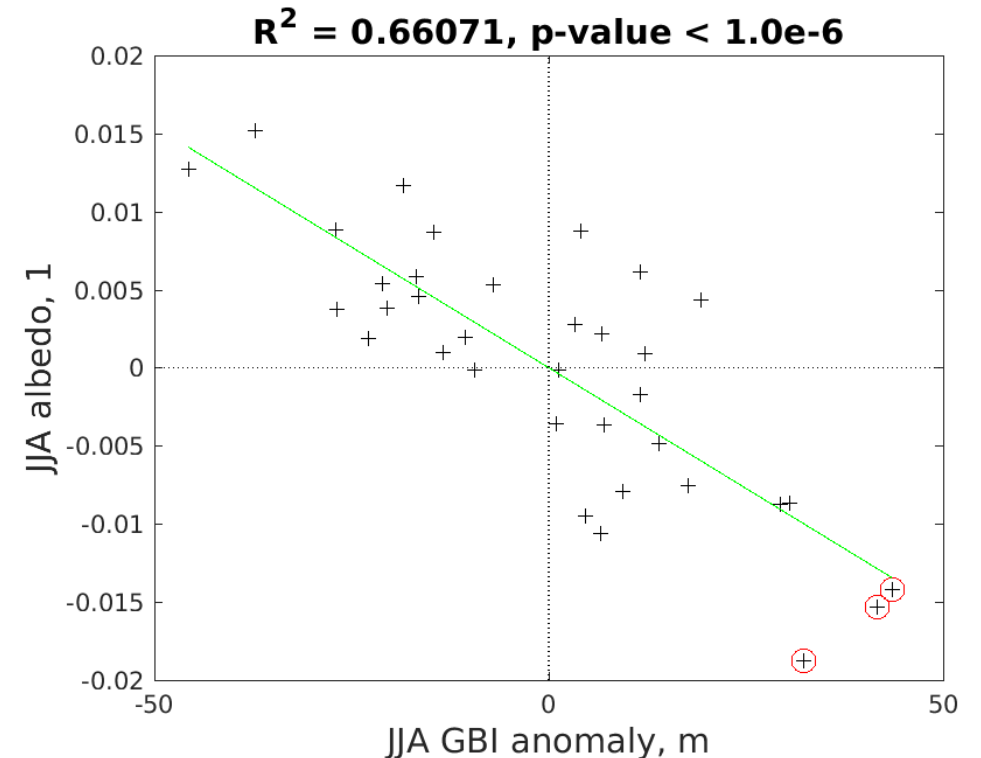
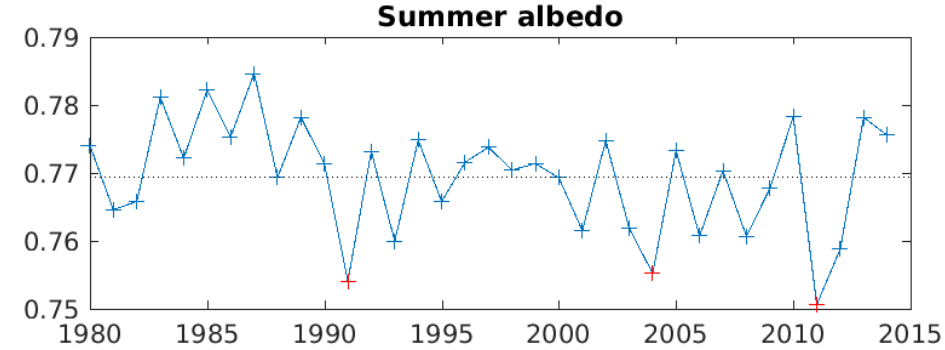
Relationship to melt

- Albedo, α : $SW_{net} = SW \downarrow (1 - \alpha)$
- Melt rate is also correlated to albedo.
- Melt rate maxima correspond to albedo minima.



Relationship to GBI

- Strong negative correlation with GBI compared to GBI and temperature.
- GBI is correlated to SW_{net} , but does not have a significant relationship with $SW\downarrow$ and is weakly correlated to cloud cover.
- Meltwater decreases albedo by increasing grain size of the ice.
- Surface melt increases when the ratio of absorbed solar radiation increases.
- Is melt-albedo feedback driving Greenland blocking anomalies?



Antony Siahhaan

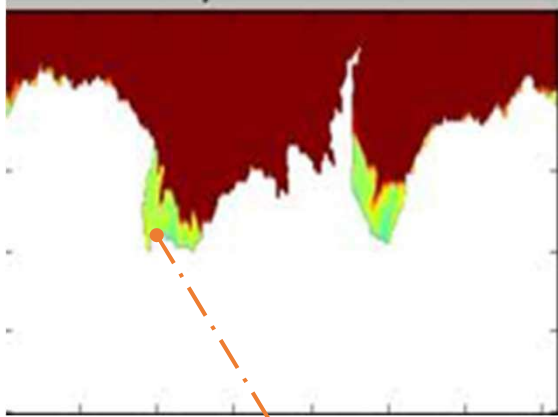
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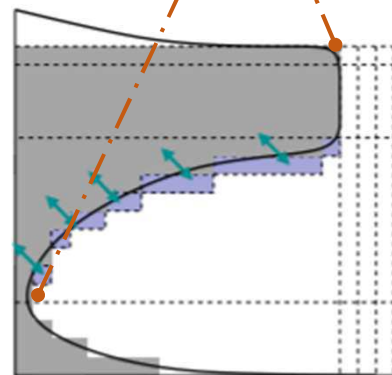
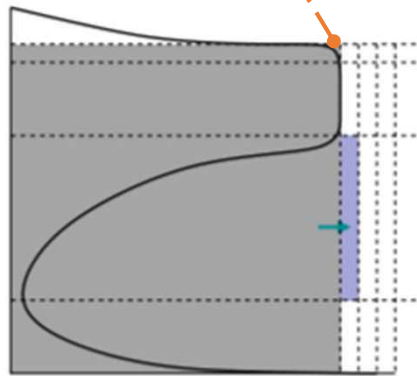
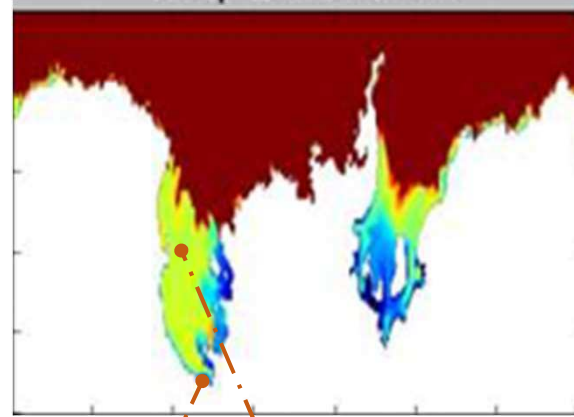
Future ocean melting of the interactive Antarctic ice shelves in UKESM

Antony Siahaan & UKESM core group members

UKESM1



UKESM1-ice



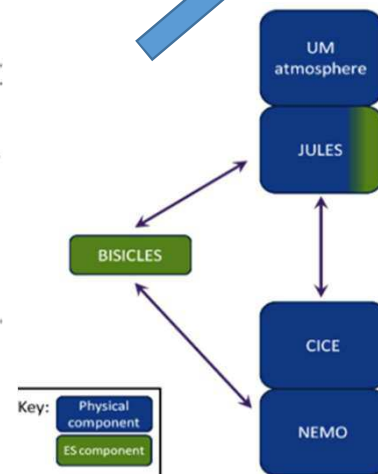
- UKESM1 : no BISICLES
- UKESM1-ice : no MEDUSA

Projection of :

- Sea-level rise
- Watermass transformation
- Ocean circulation
- Atmospheric processes
- Biogeochemistry: with MEDUSA

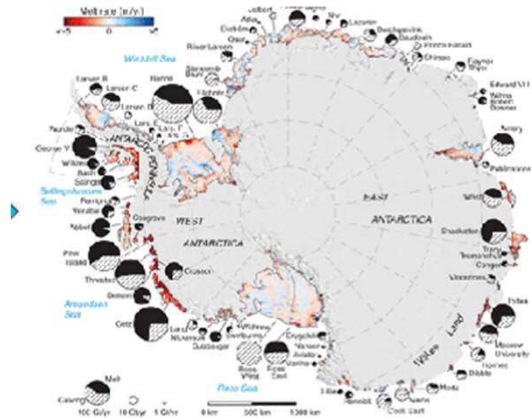
Scenario runs :

- SSP1-1.9 : 2 members
- SSP5-8.5 : 2 members
- Initialised with UKESM1 historical members
- Cavity data is initialized with standalone NEMO-CICE spinup
- Ice geometry is initialized with standalone BISICLES spinup



Meltrate Pattern

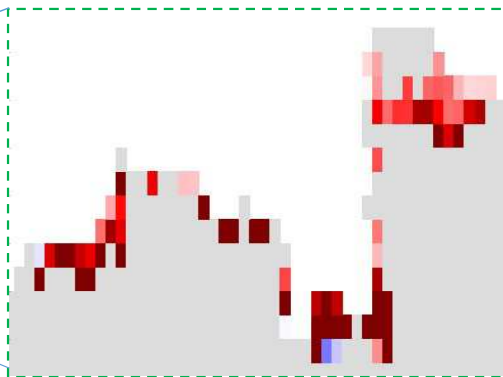
Observation



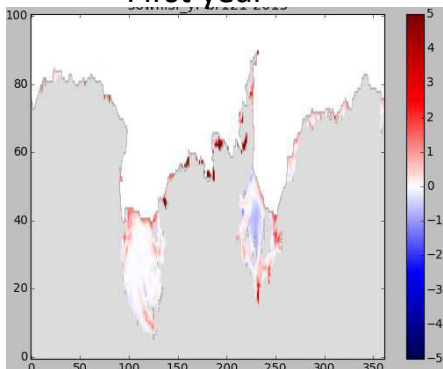
SSP1-1.9

SSP5-8.5

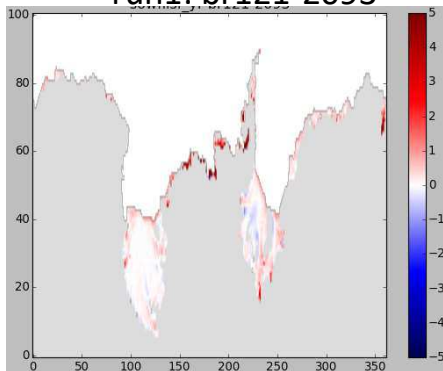
Amundsen Sea



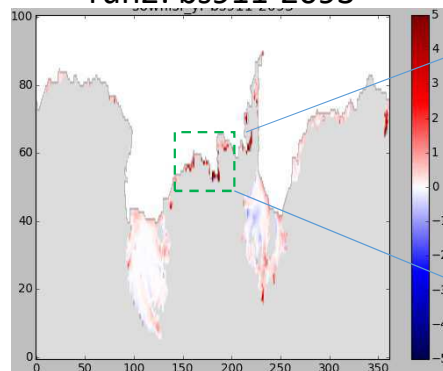
First year



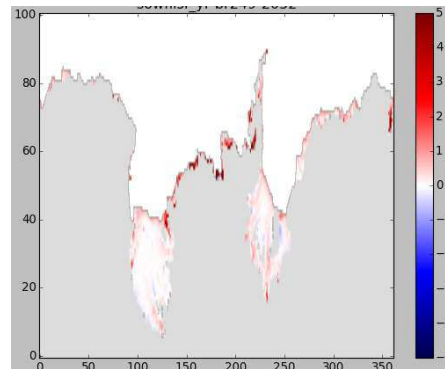
run1: br121-2093



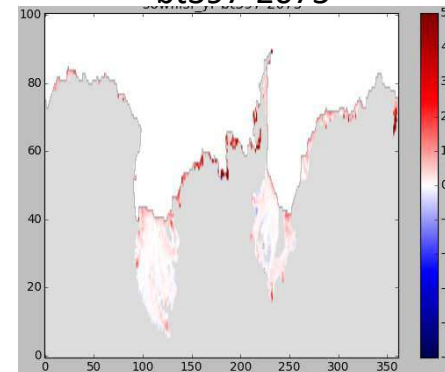
run2: bs911-2093



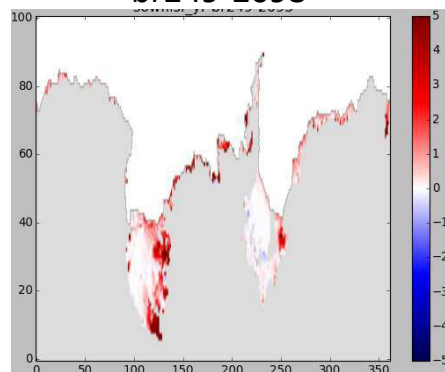
br249-2052



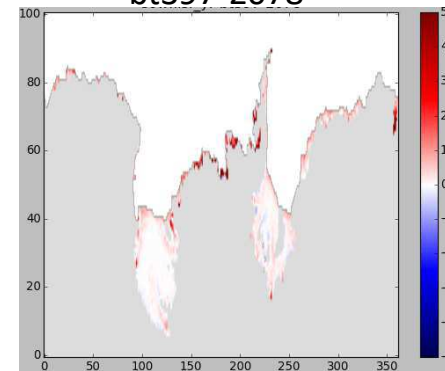
bt397-2075



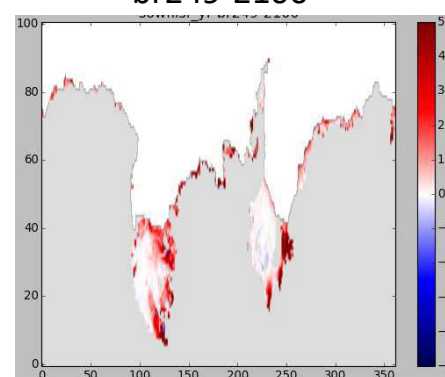
br249-2093



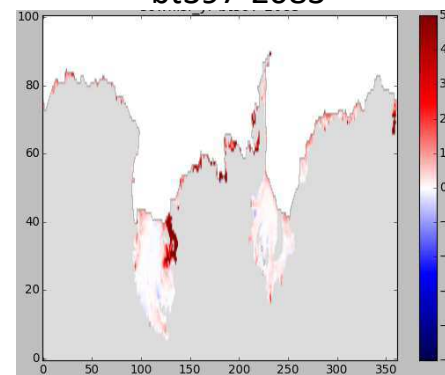
bt397-2078



br249-2100



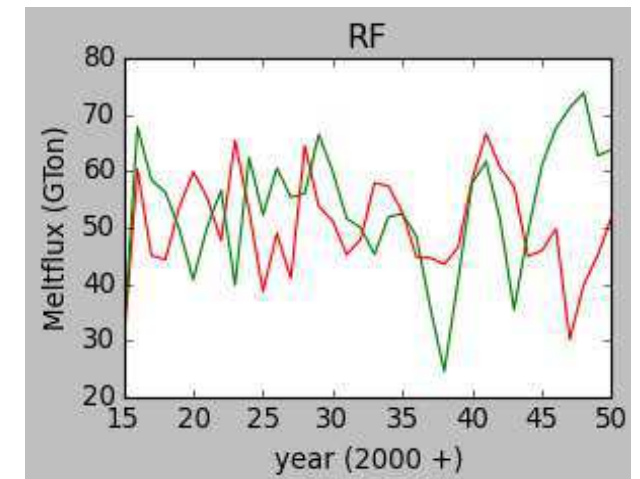
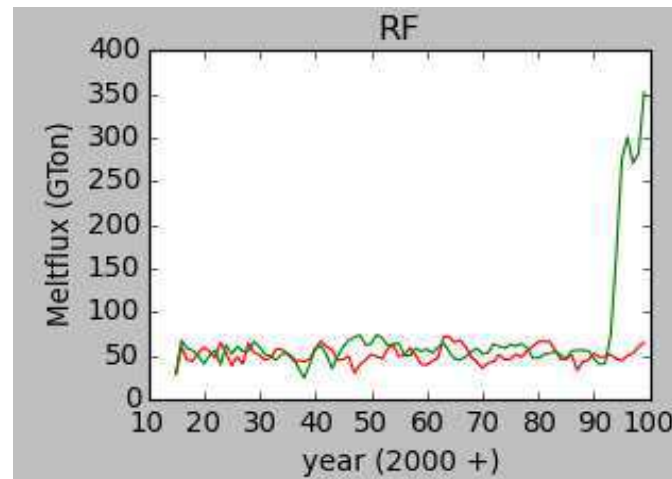
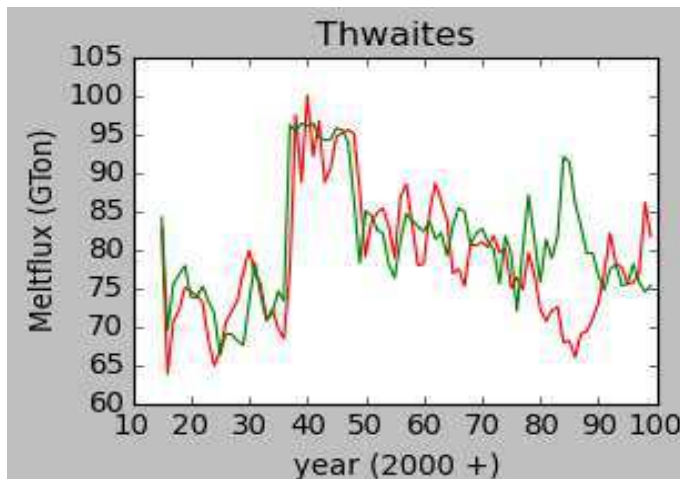
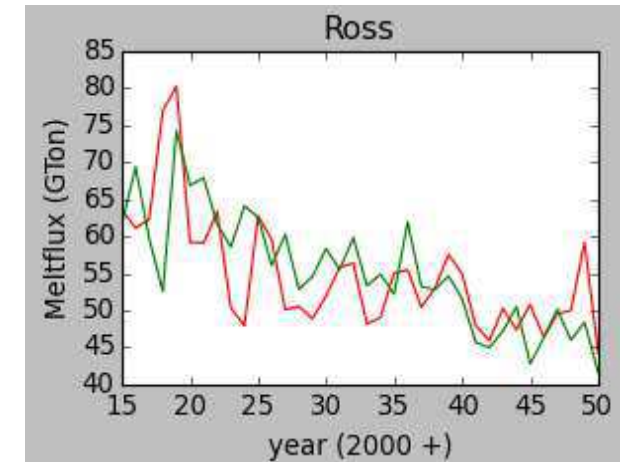
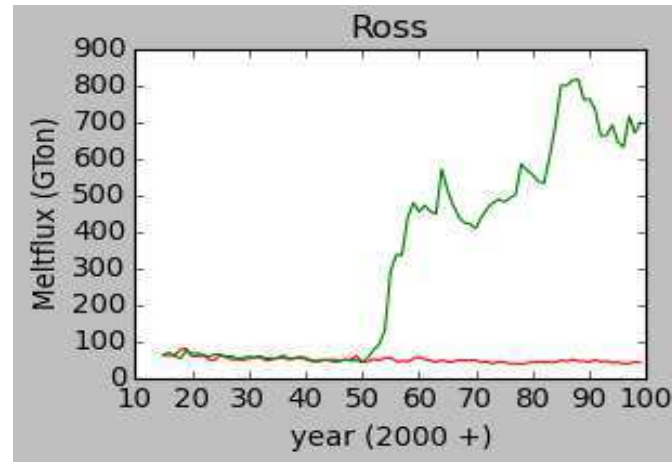
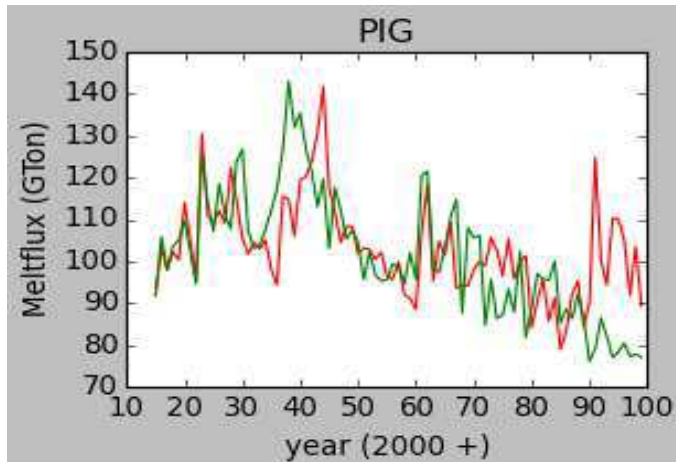
bt397-2083



Meltflux time-series

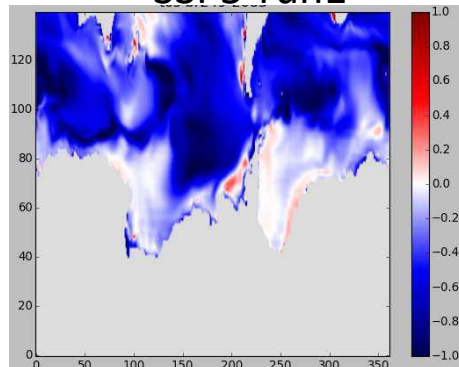
- 2013 observation : PIG = 90 to 110 Gton/year; Thwaites = 80 to 100 GT/year
Ross = 24 to 70 Gton/year ; RF = 105 to 200 GT/year

Green : SSP5
Red : SSP1

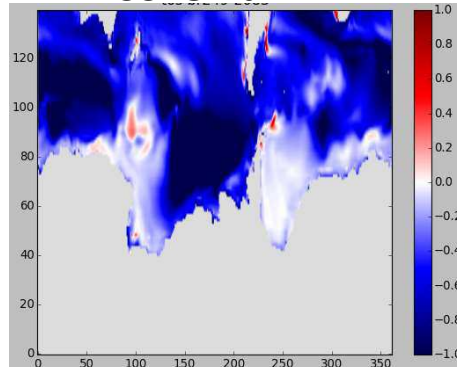


UKESM1-ice - UKESM1 (2060-2070 mean)

SSP5-run1

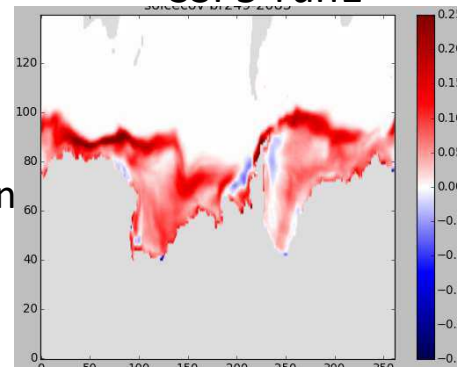


SSP5-run2

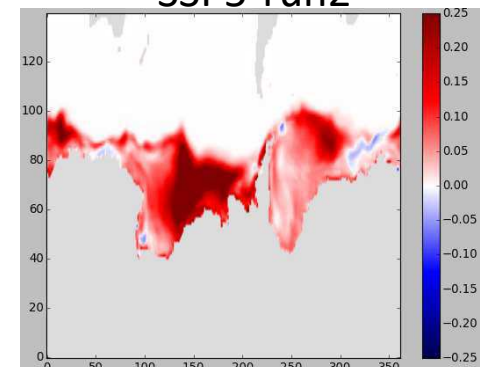


SST

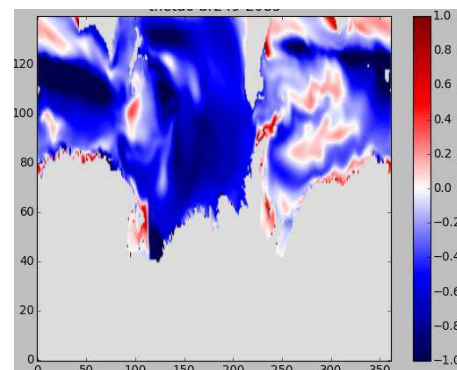
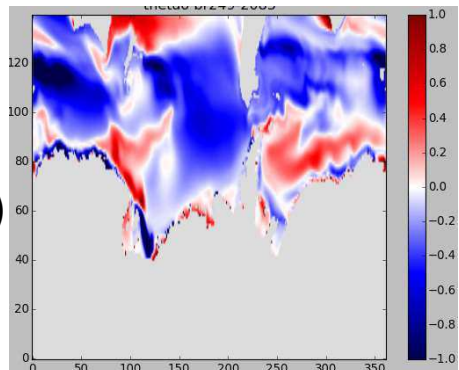
SSP5-run1



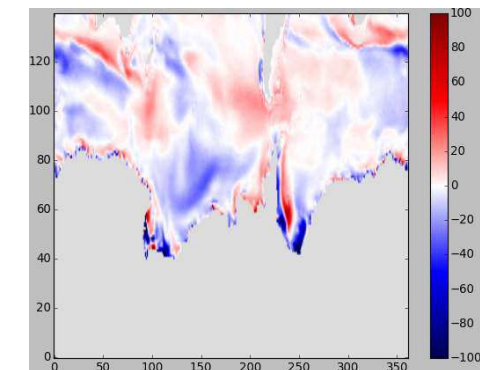
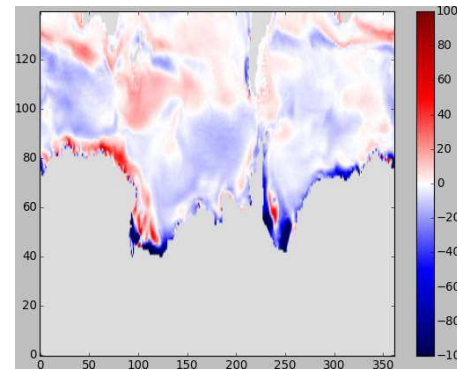
SSP5-run2



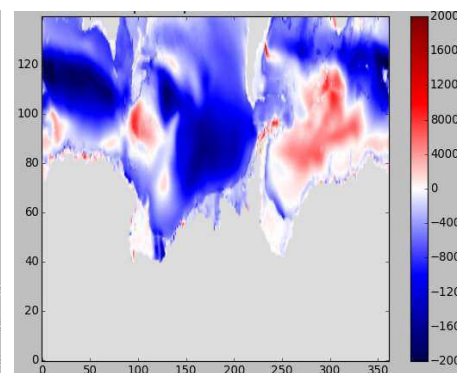
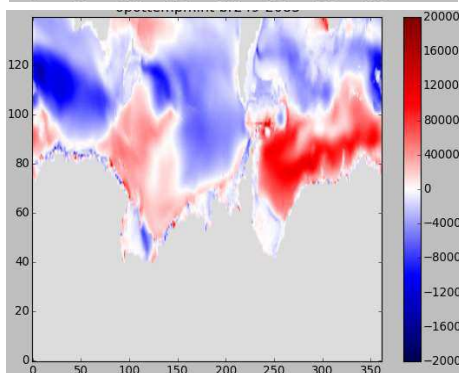
Seaice
fraction



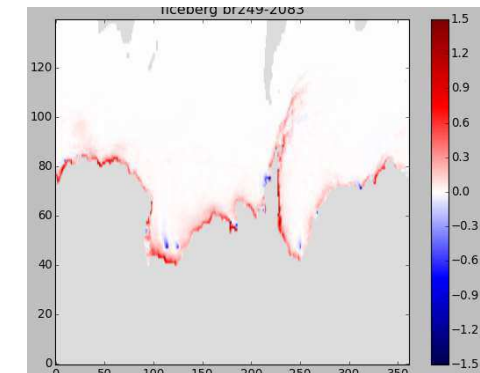
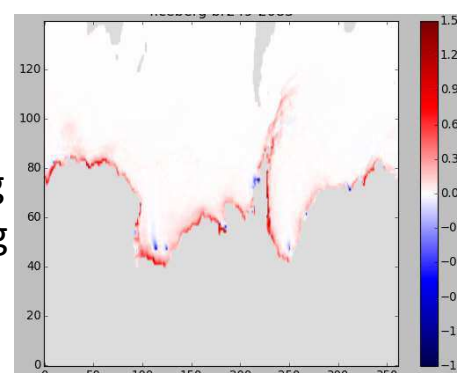
T(400m)



Max
MLD



Heat
content



Iceberg
melting

João Teixeira

Met Office



Coupling interactive fire with atmospheric composition and climate in the UKESM

João Teixeira^{1,2}, Gerd Folberth¹, Fiona M. O'Connor¹, Nadine Unger², Apostolos Voulgarakis^{3,4}

¹Met Office, Fitzroy Road, EX1 3PB, Exeter, UK

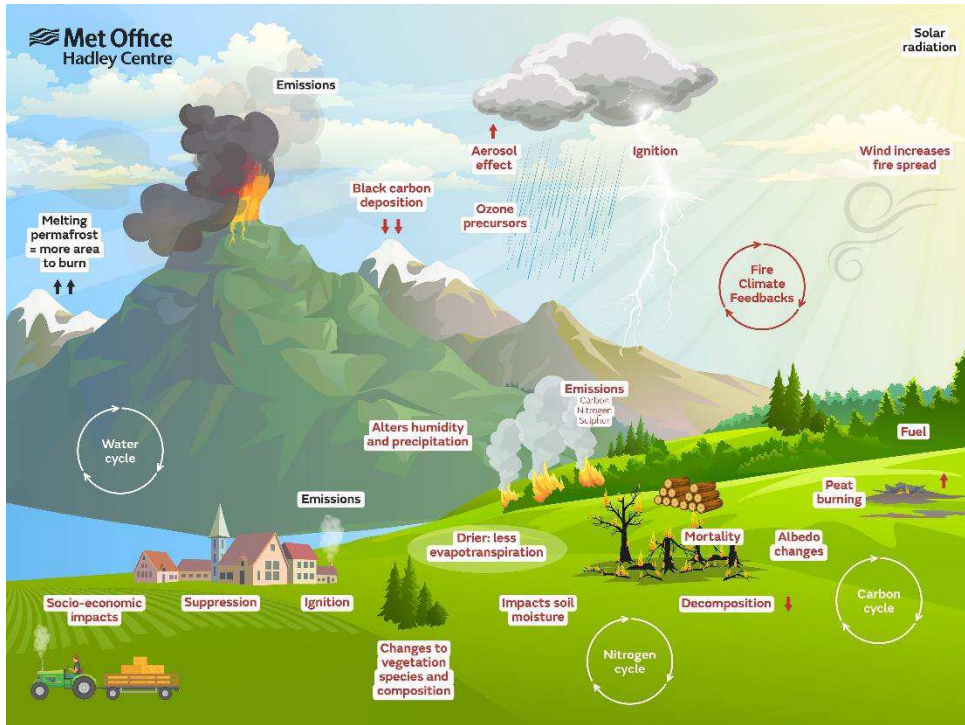
²College of Engineering, Mathematics and Physical Sciences, University of Exeter, Exeter, UK

³Leverhulme Centre for Wildfires, Environment and Society, Department of Physics, Imperial College London, London, UK

⁴School of Environmental Engineering, Technical University of Crete, Chania, Greece



Fires can exert a substantial forcing on the Earth's climate by affecting different components of the Earth System



- Largest source of carbonaceous aerosol globally
 - ~ 60 % of the of primary OC and BC aerosol emissions
 - Dominant source for central Africa and Amazon regions
- Total net negative radiative effect of -1.02 W m^{-2} pre-industrial period (1850) ([Ward et al. 2012](#))
- Low agreement on the regional changes in future fire regimes
- Global scale assessments highlight the complexity and uncertainties of these impacts

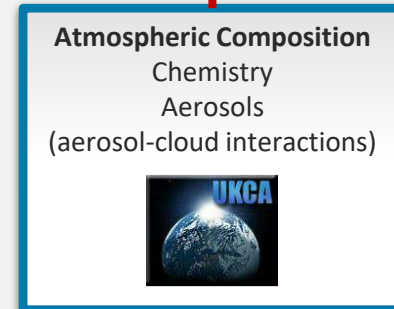
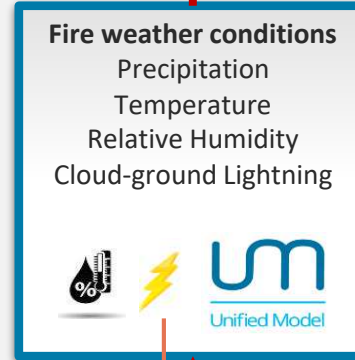
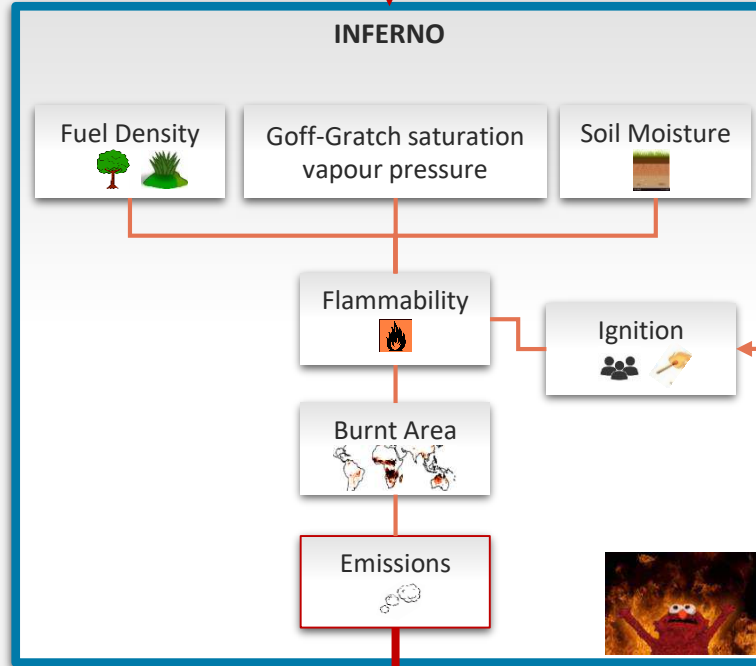


Total radiative effect of fires remains uncertain making climate-fire feedbacks relevant in the context of climate change research

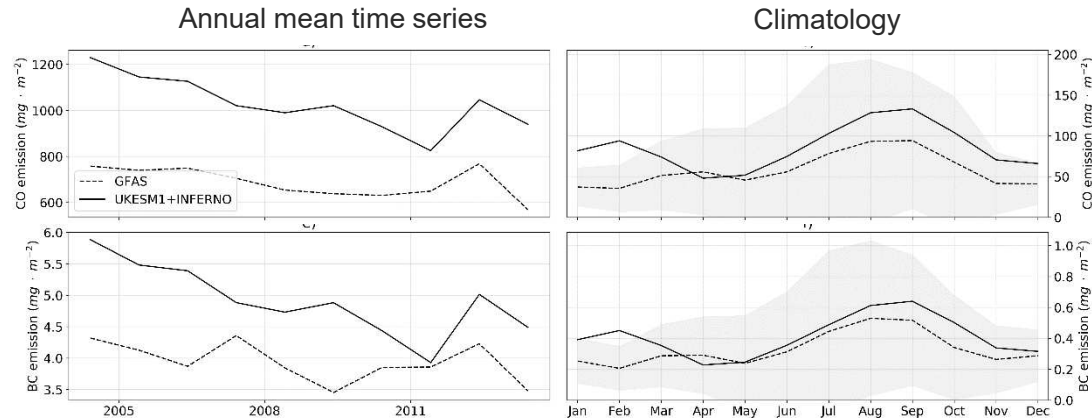
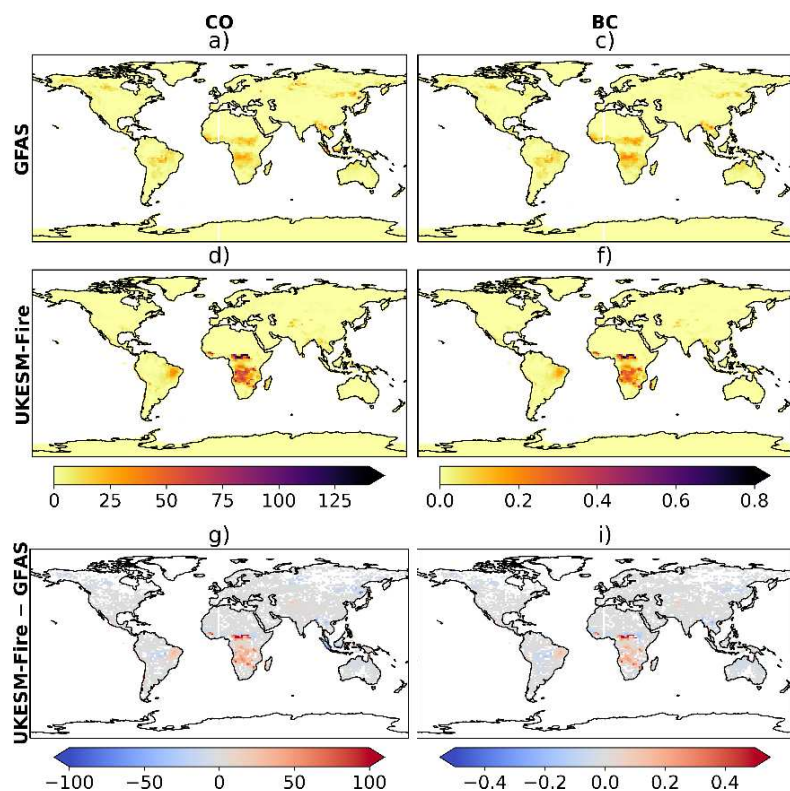
Objective → Development and evaluation of a coupled fire-composition-climate Earth system model

Coupling framework

UKESM1 – AMIP (Historical)



Biomass burning emissions (kg m^{-2}) mean annual average (1997 - 2010)



- Global pattern well reproduced
- Large overestimation of the biomass burning emissions
 - NHAF
 - SHAF – emissions extend further south
 - SHSA – large bias on the eastern edge
- Underestimation over the peatland regions (e.g. Indonesia and boreal regions)
- Large bias in the annual mean time series
- Seasonal cycle well reproduced – partially due to regional compensating bias

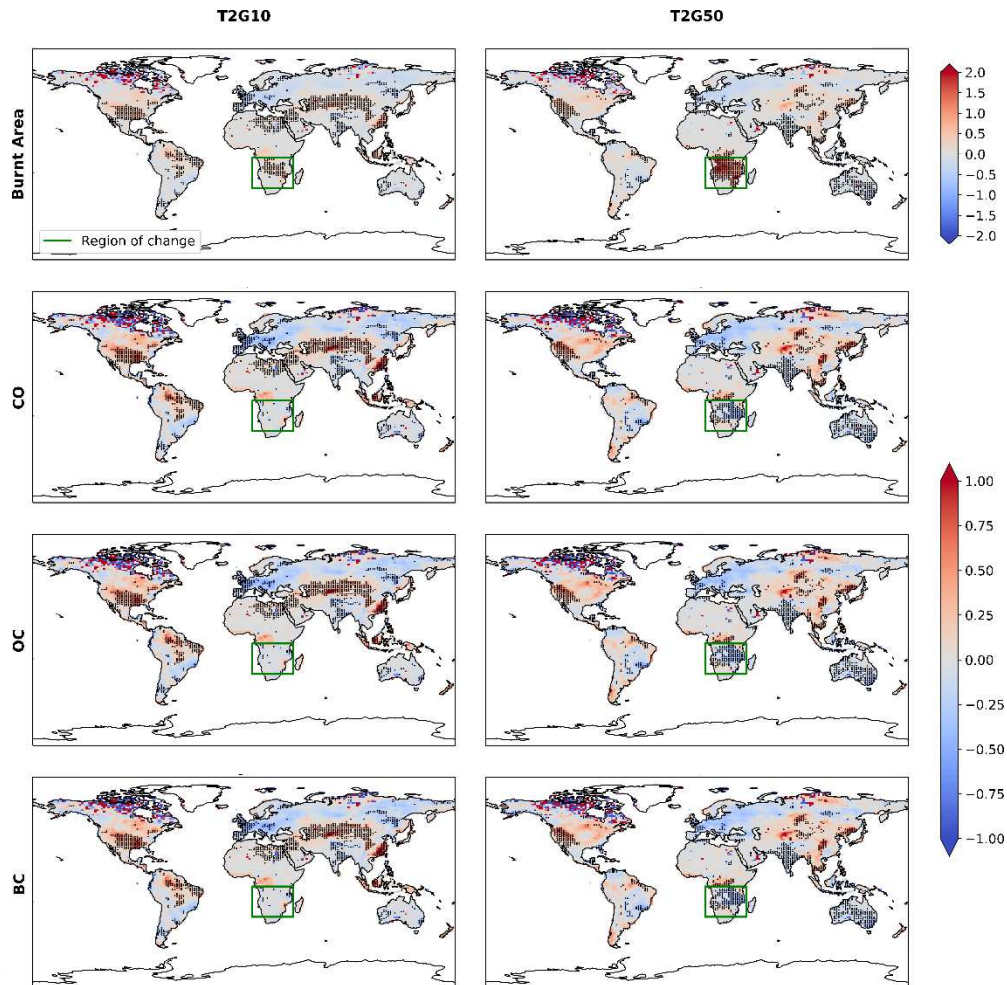
Land surface sensitivity

Two sensitivity experiments (1980 – 1985):

- **T2G10** – 10 % of trees are changed to grass
- **T2G50** – 50 % of trees are changed to grass
- Specific region in SHAF

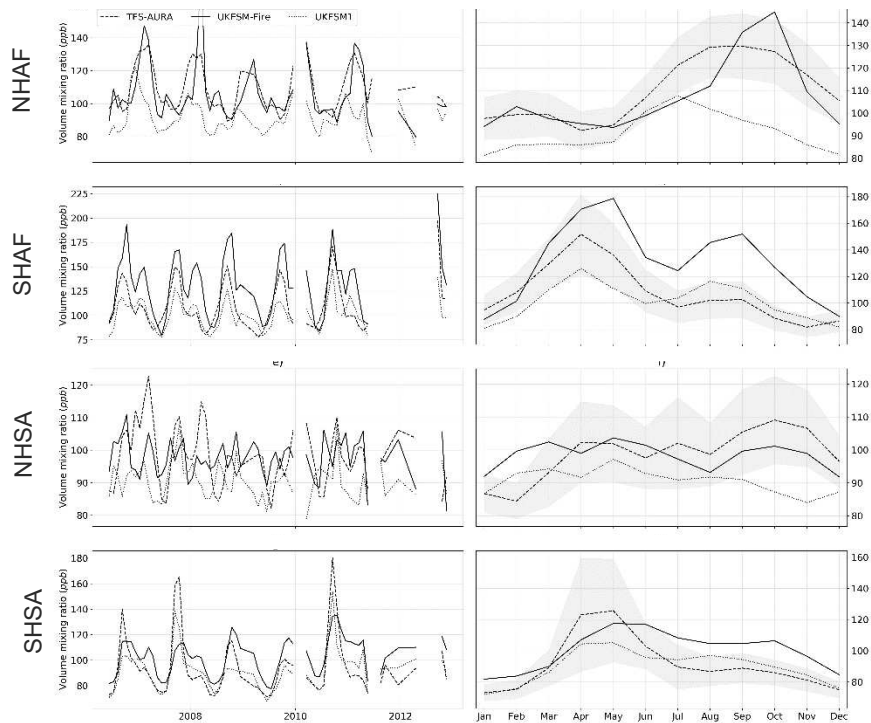
		Burnt Area (Mha)	CO (g m ⁻²)	OC (g m ⁻²)	BC (g m ⁻²)
Global	UKESM-Fire	243.95	25.29	1.14	0.12
	T2G10	256.29 (+5.05 %)	25.90 (+2.41 %)	1.12 (-1.75 %)	0.12 (0.00 %)
	T2G50	290.31 (+19.00 %)	24.68 (-2.41 %)	1.08 (-5.26 %)	0.11 (-8.33 %)
SHAF	UKESM-Fire	49.05	8.61	0.36	0.42
	T2G10	55.02 (+12.17 %)	8.45 (-1.85 %)	0.35 (-2.78 %)	0.41 (-2.44 %)
	T2G50	88.21 (+79.83 %)	7.55 (-13.31 %)	0.31 (-15.15 %)	0.36 (-14.28 %)

- Burnt area hypersensitive to this land surface change
- Significant changes in emissions for T2G50
- Regional changes in the land surface can have remote impacts

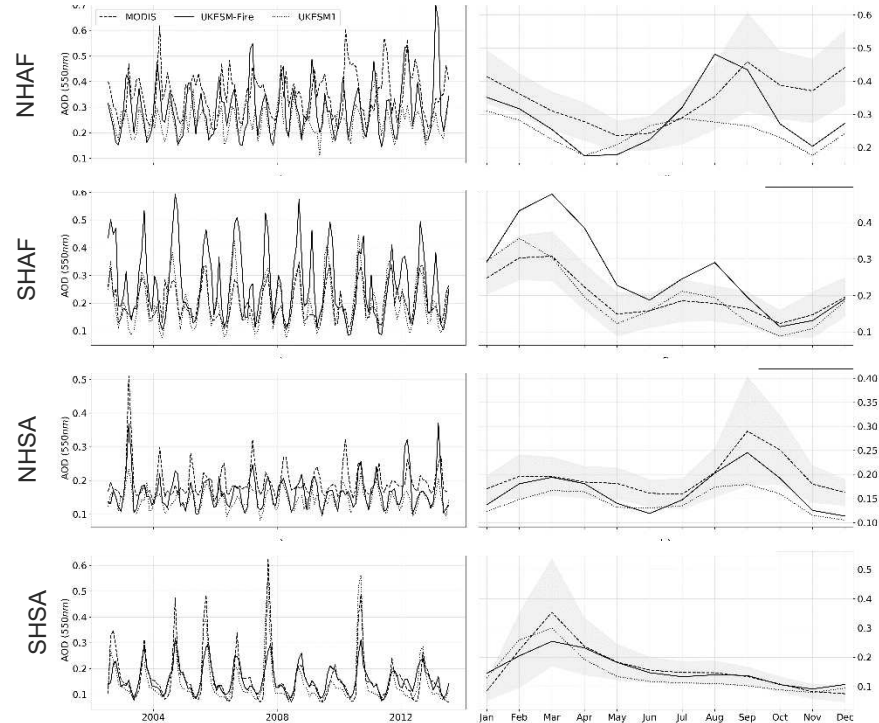


CO and AOD monthly mean time series and climatology

CO column volume mixing ratio (ppm) averaged between 700 and 300 hPa



AOD at 550 nm



- Improves interannual CO variability and seasonality over the studied regions
- overestimation of AOD over NHAF and SHAF regions
- improvement of the variability and seasonality of AOD in South America,
- Does not capture the spikes in AOD, or CO observed over SHSA during the period 2004 to 2007 and 2010

Summary

- ❖ Coupling a fire model to UKESM1 results in a similar performance in reproducing the distribution of aerosols and CO atmospheric column.
- ❖ Limitations of current set-up
 - No fire-vegetation feedbacks
 - Peat fires are not represented
 - Underlying vegetation bias can have a significant impact in modelled results
- ❖ This shows that we have developed a useful coupling framework that allows the representation of complex fire-composition-climate interactions and feedbacks in the Earth system

Future work

- ❖ Include fire-vegetation feedbacks - brings improvements to Africa and South America
- ❖ Include representation of peatland fires - impact in the northern hemisphere
- ❖ Study and quantify the impacts of fire in climate change scenario and on atmospheric composition-climate interactions

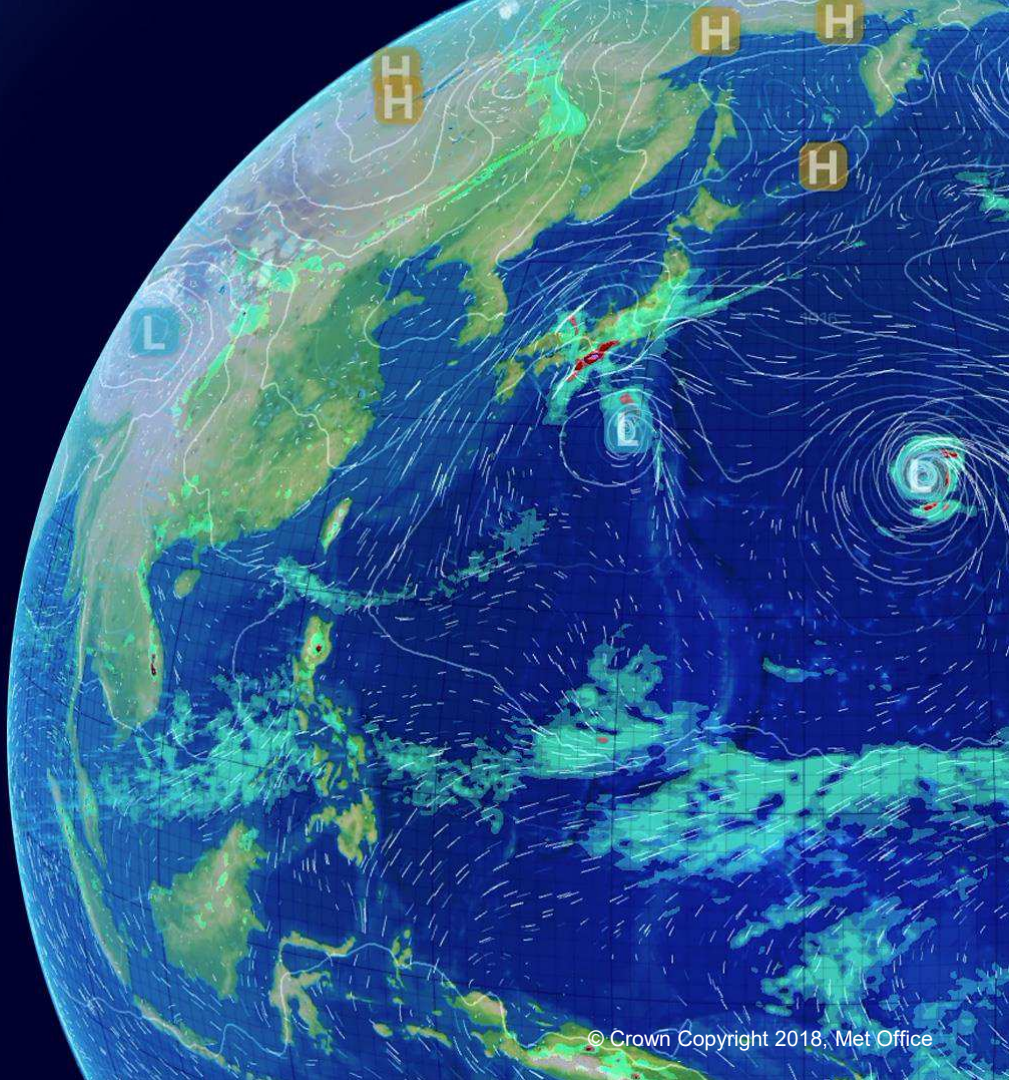
Chantelle Burton

Met Office



Coupling fire into UKESM

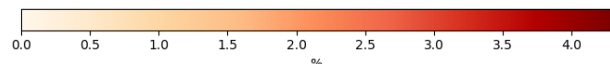
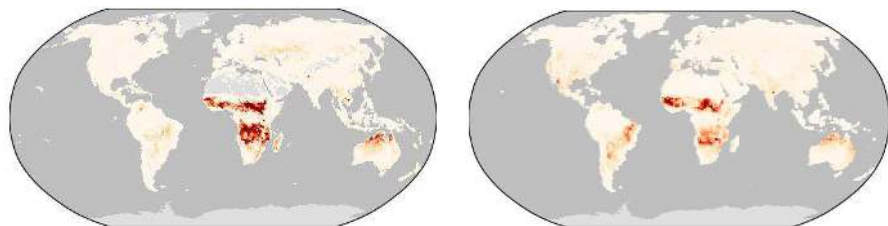
Chantelle Burton, João Teixeira, Doug Kelley, Andy Wiltshire



Offline runs (JULES-ES)

GFED4s (observations)

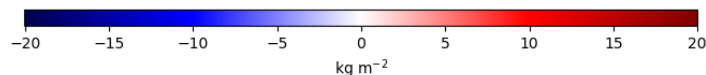
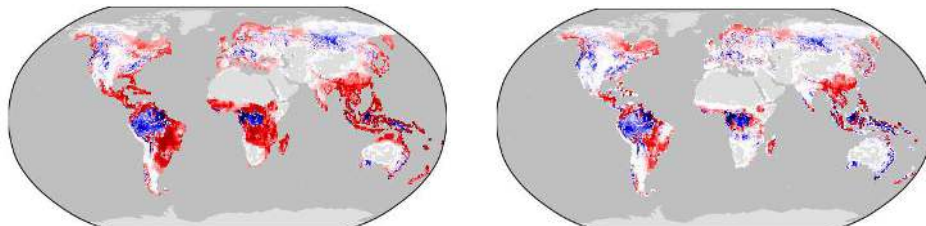
JULES-ES



Monthly percentage burned area

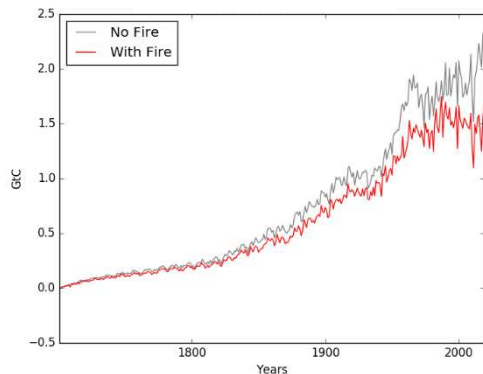
No Fire

With Fire



Bias in vegetation carbon (compared to GEOCARBON)

NBP S2-S3



Net Biome Productivity

Present day:

No fire = 2.0 GtC

With fire = 1.5 GtC

GCP estimate as a residual of
other carbon fluxes = 2.1 +/- 0.7

TRENDY models = 1.0 +/- 0.8

2009-2018

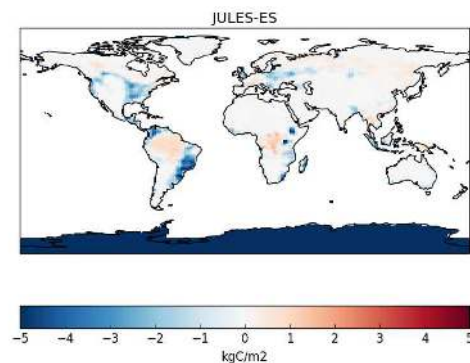
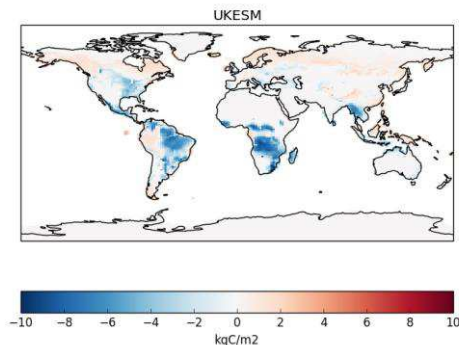
S2 = no land use change

S3 = with land use change

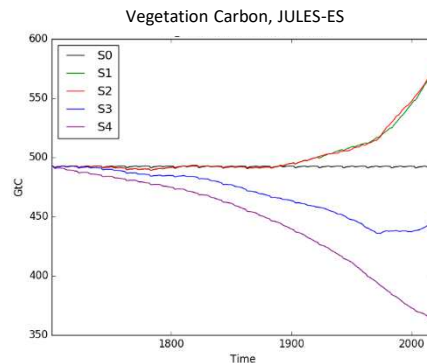
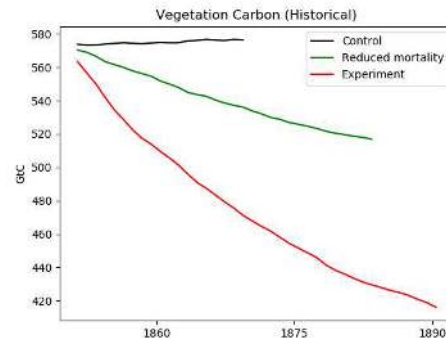
Variable	Obs estimates	JULES-ES	JULES-ES +fire
Vegetation Carbon	~460 GtC (IPCC AR5)	~630 GtC	~445 GtC
NPP	~55 GtC	~78 GtC	~70 GtC
GPP	~100-130 GtC	~150 GtC	~130 GtC

Fully coupled UKESM runs with fire

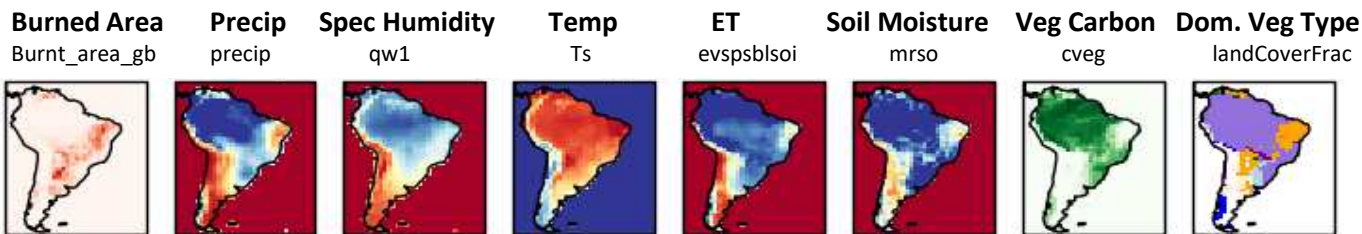
- UM vn 11.6, JULES vn 5.7
- Emissions and atmospheric chemistry, lightning from UM, fire mortality and dynamic vegetation
- 4xCO₂, PIC and historical
- Strong response to fire -> vegetation carbon reduction
- Experimenting with reducing fire mortality rate



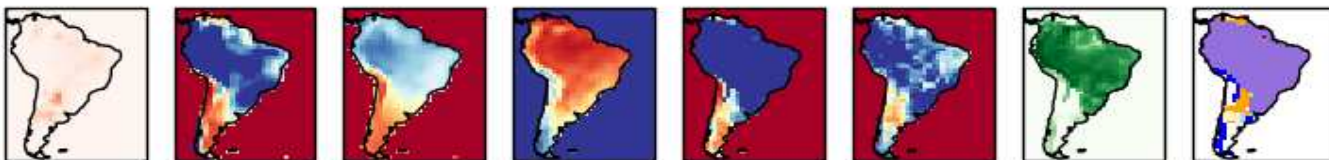
Change from 1860s to 1960s in UKESM historical run and JULES-ES



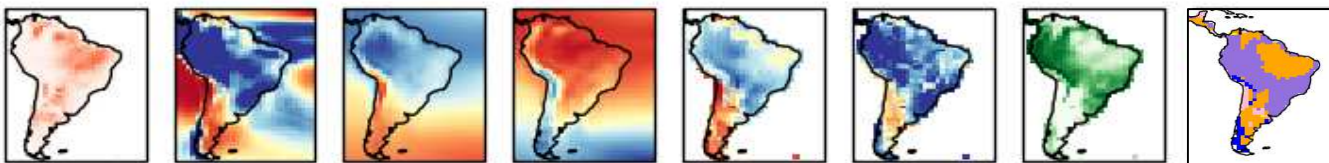
S3 (blue)= with land use change



JULES
with
UKESM
forcing

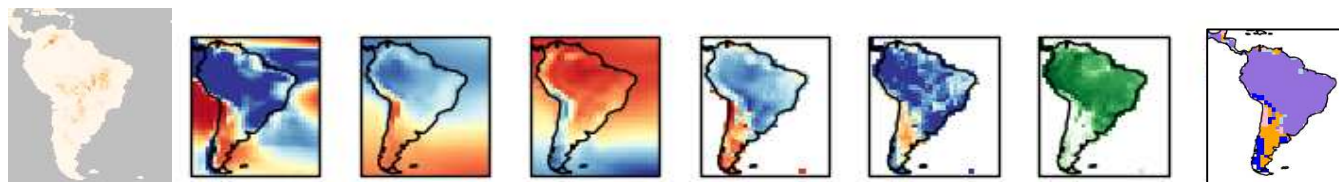


UKESM
with fire



UKESM
without fire

Burned
area =
GFED



0.0 0.1 0.2 0.3 0.4
Gridbox fraction
#8700

0 1000 2000.00
kg/m²/yr
#5216

0.01 0.02 0
kg/m²
#3237

0 15 30
°C
#3236

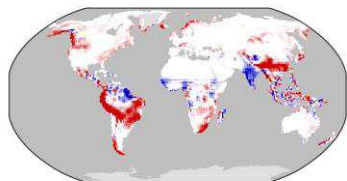
0 500 1000
kg/m²
#3288

0 500 10000
kg/m²
#8223

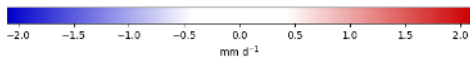
0 10 20
kg/m²
#19002

BLE-Tr
C4 grasses

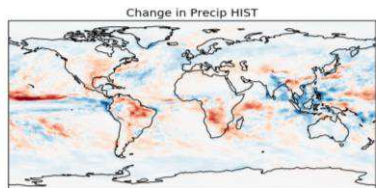
Precipitation



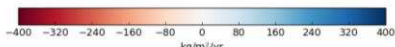
UKESM
bias



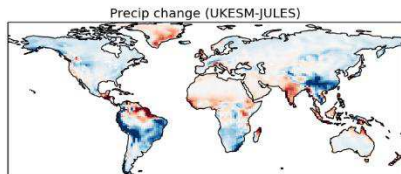
ilamb bias against CMAP



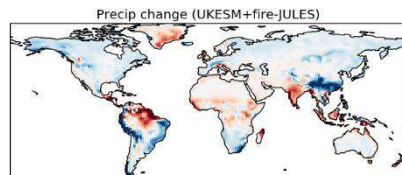
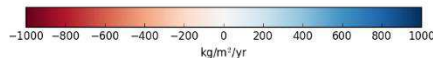
Fire
impacts



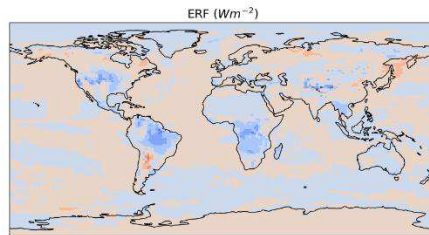
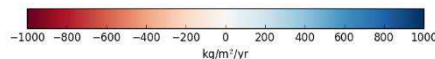
30 year mean (1930-1960)
HIST+fire – HIST CTRL



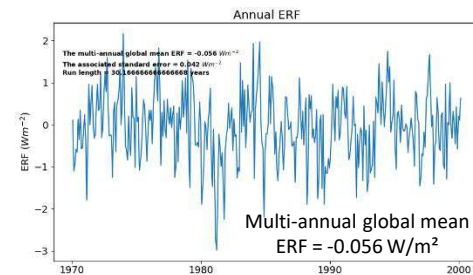
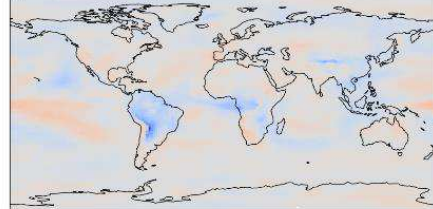
30 year mean (1970-2000)
PI control (aw310) – JULES



30 year mean (1970-2000)
PI control (bs209)+ fire – JULES

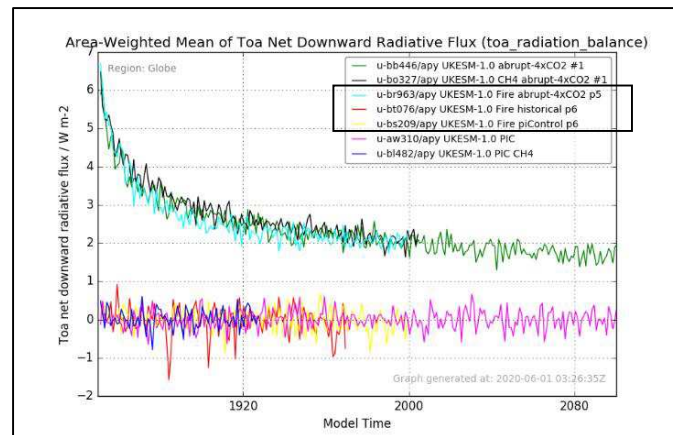


total_cloud_fraction - averaged over 1970-01-16 00:00:00 - 2000-02-16 00:00:00



Atmosphere and radiation

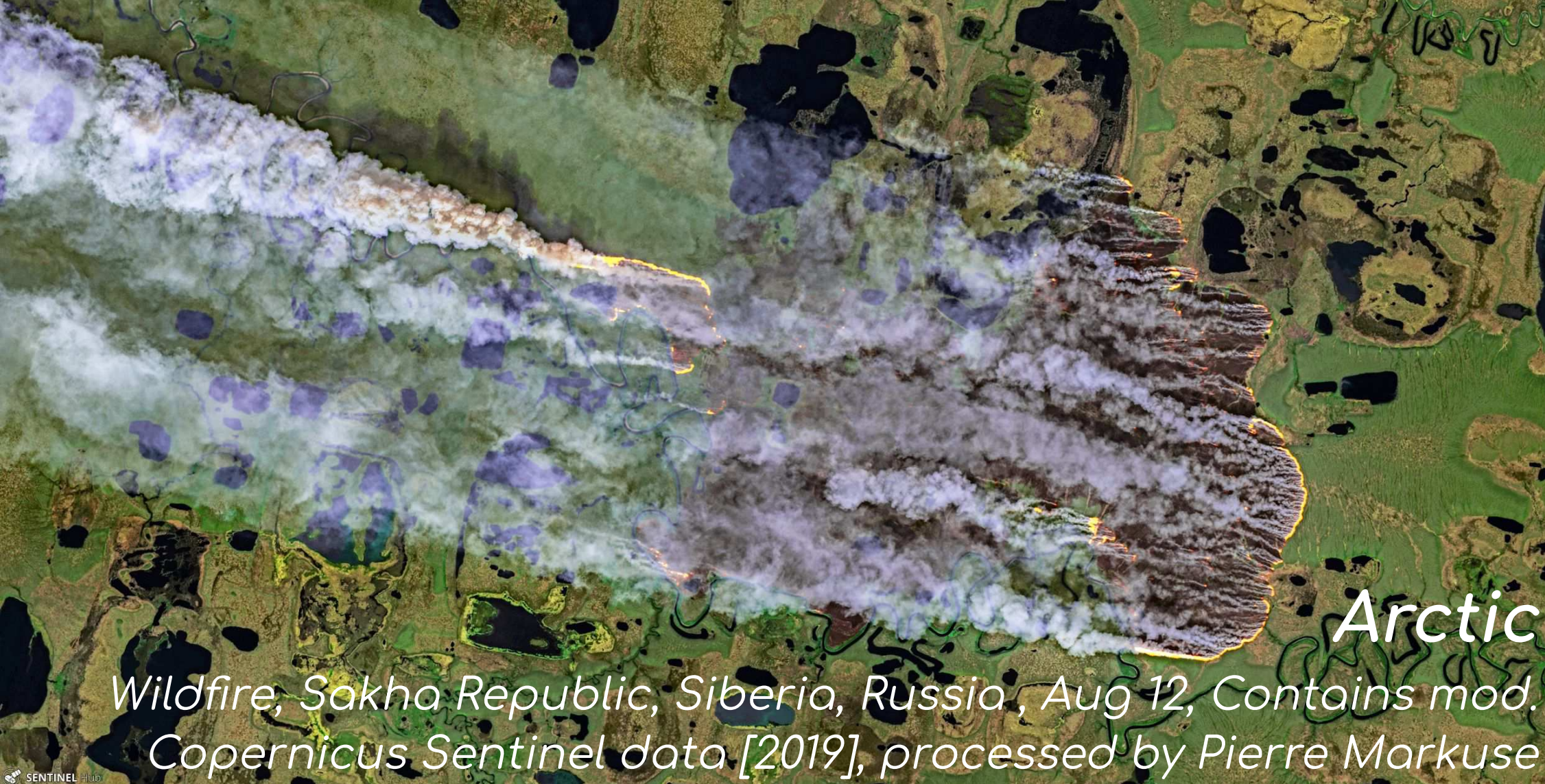
PIC+fire - PIC



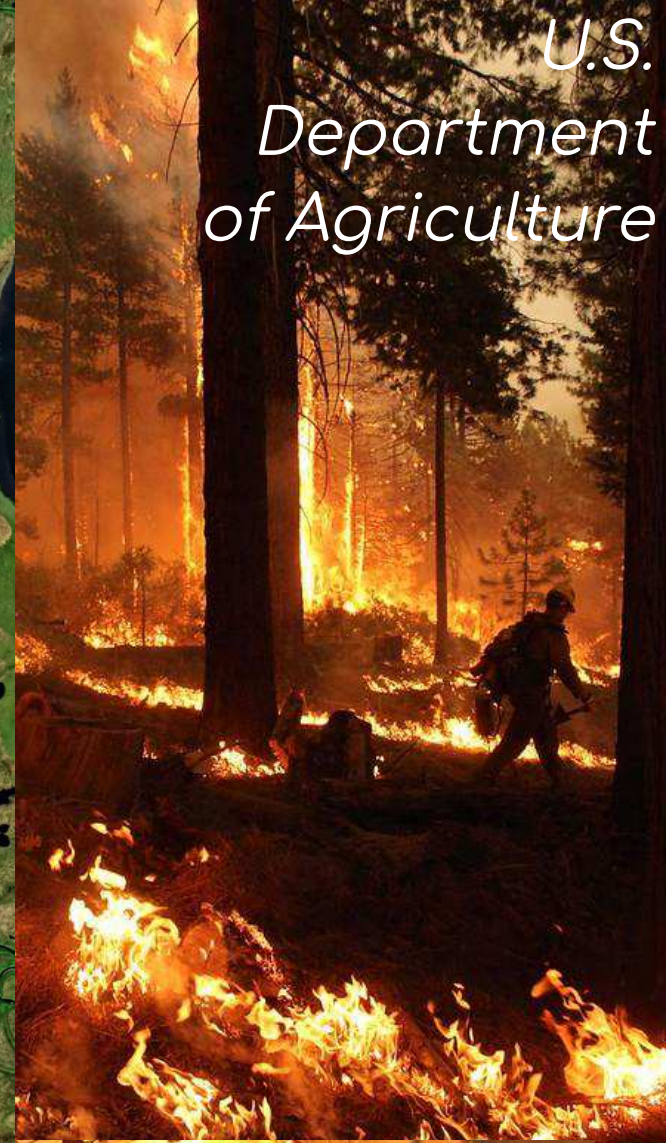
Douglas Kelley

CEH





Arctic
Wildfire, Sakha Republic, Siberia, Russia, Aug 12, Contains mod.
Copernicus Sentinel data [2019], processed by Pierre Markuse



U.S.
Department
of Agriculture



NSW/Queensland
NSW RFS Mathoura 1B by Russell Perry



Amazon
Fires in the Amazon rainforest by
ESAs Luca Parmitano on the ISS



U.S. Department
of Agriculture



NSW Rural Fire Service



Slash and burn agriculture in the Amazon,
Mott Zimmerman



GREG MATTHEWS

California
Greg Matthews #DetectiveGreg

Preserving uncertainty in fire model parameterisation

Douglas Kelley, Chantelle Burton,
Rhys Whitley, Ioannis Bistinas,
Dong Ning, Chris Huntingford,
Megan Brown, Toby
Marthews, João Teixeira, Rob
Parker, Rich Ellis,

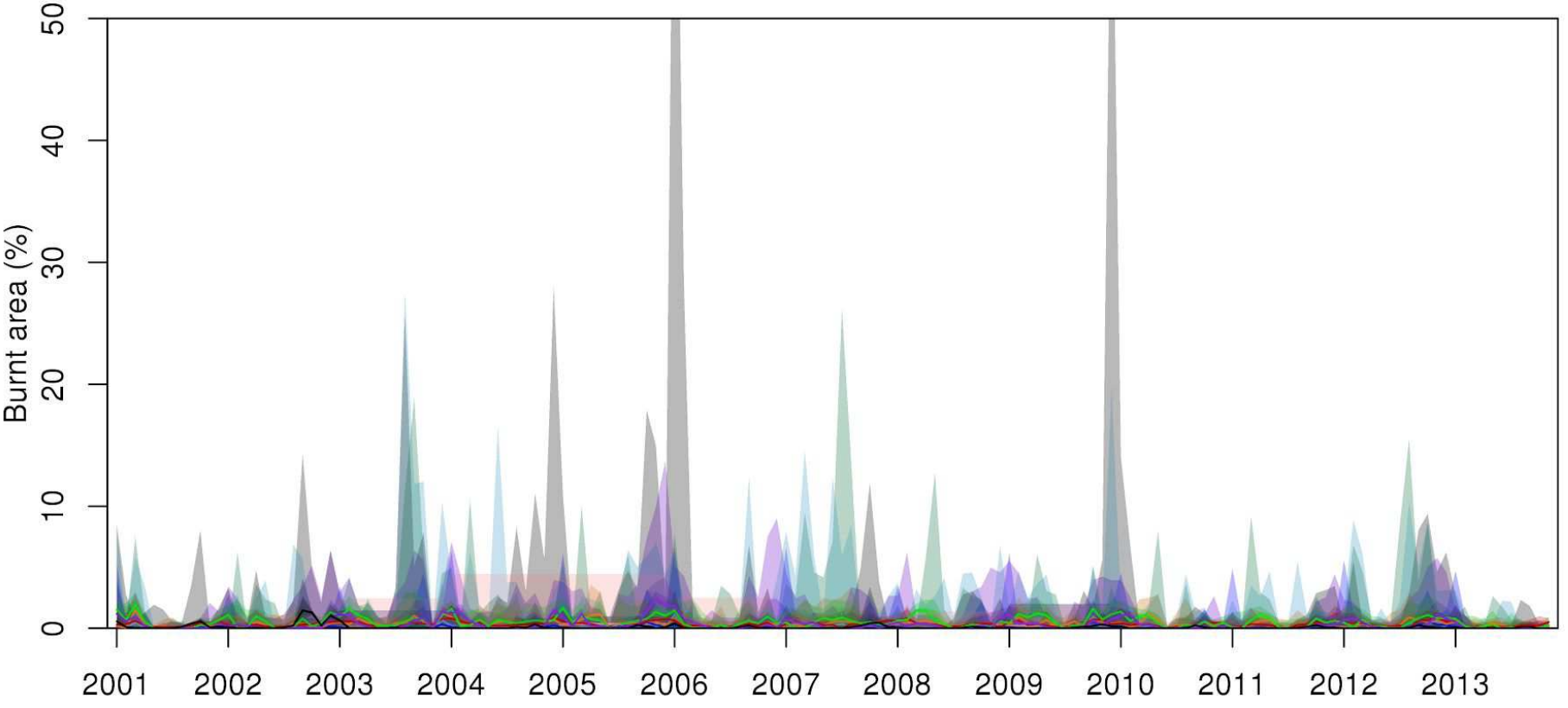
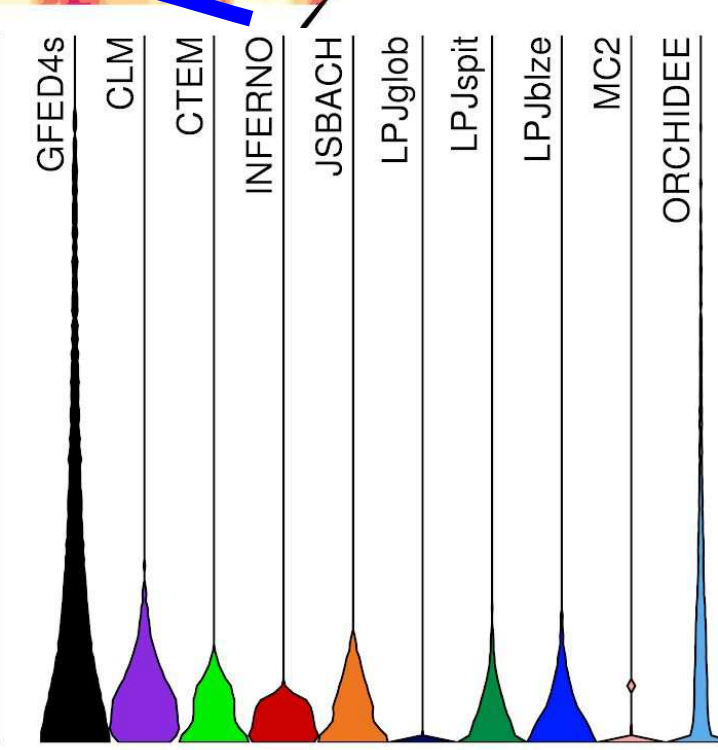
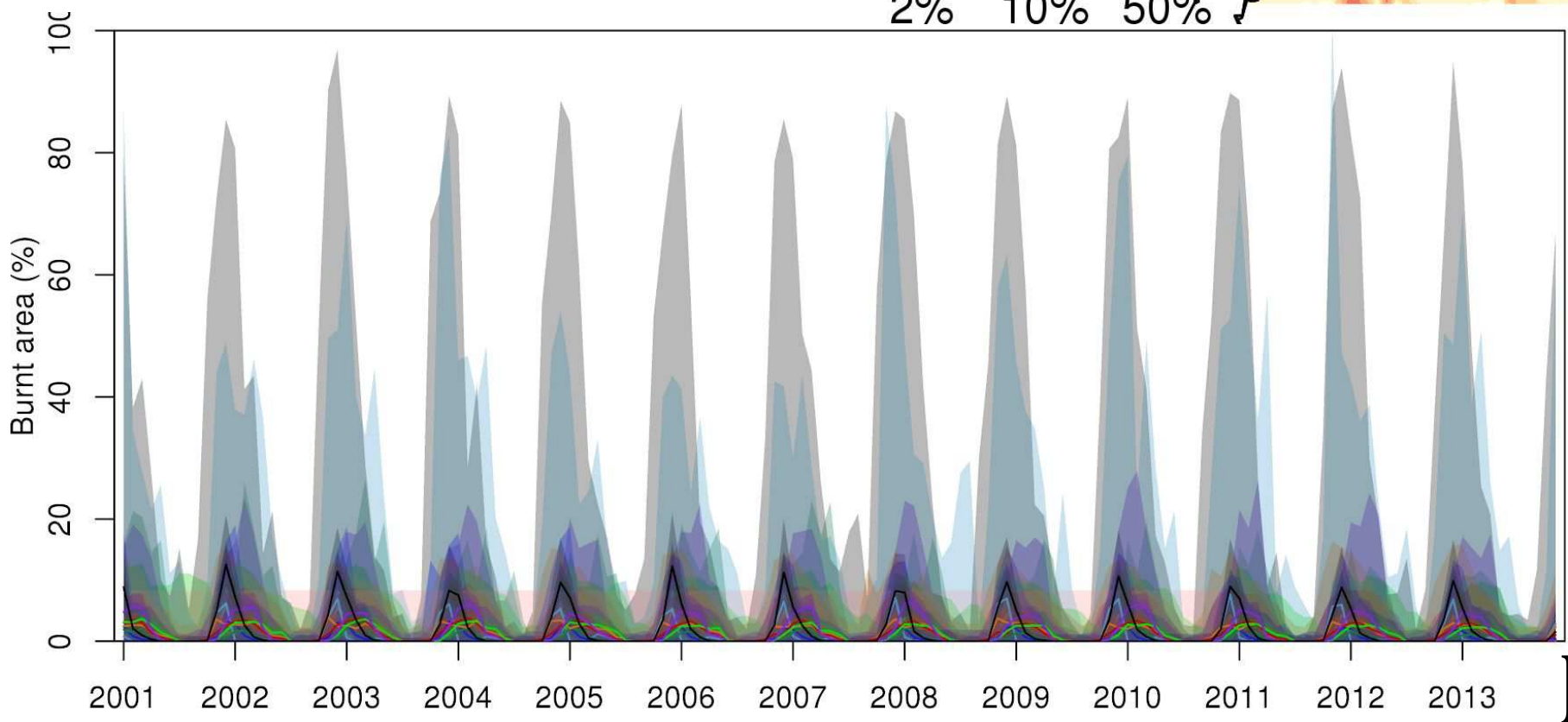
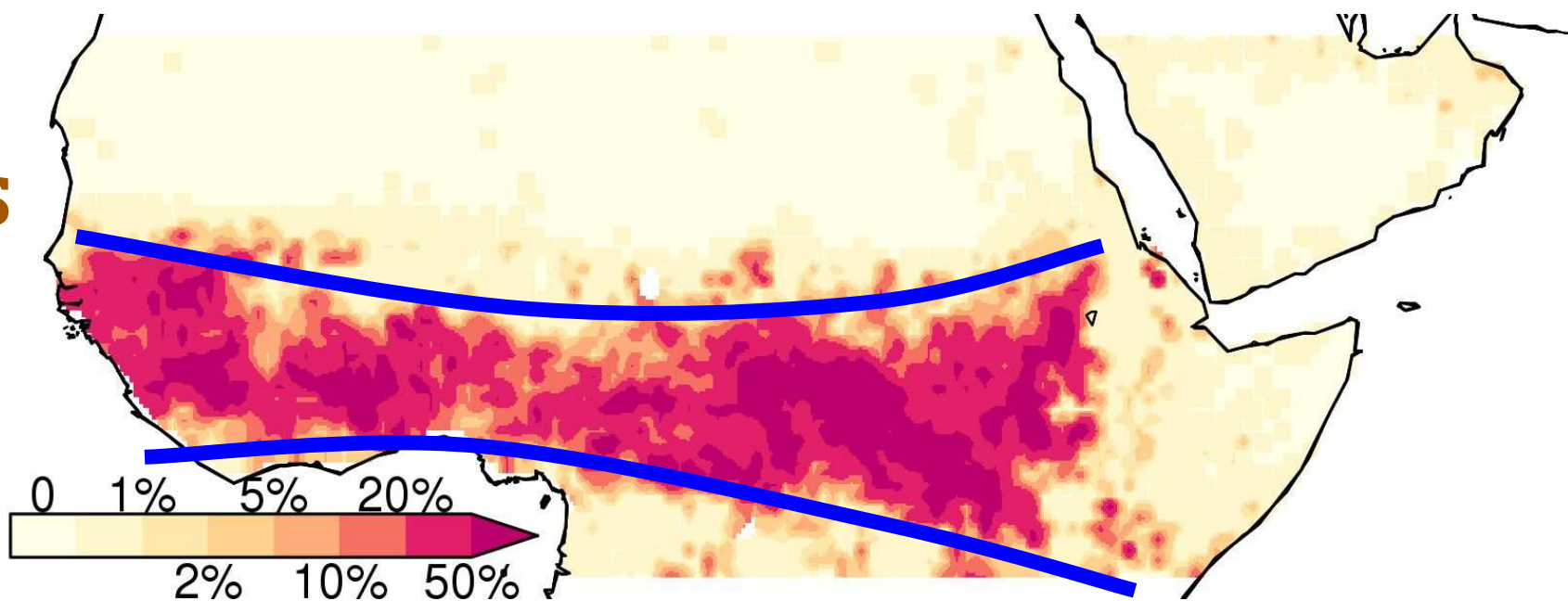
and many more...



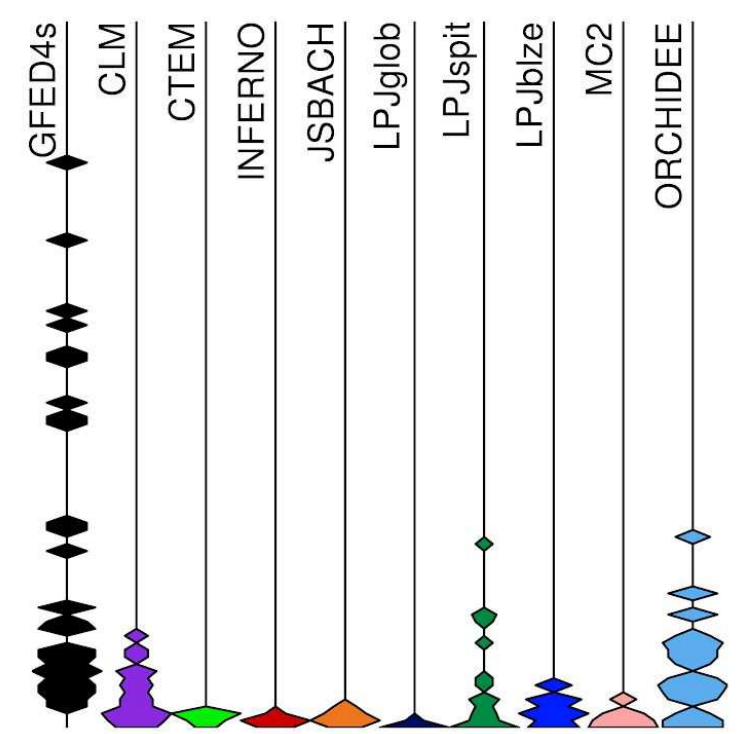
UK Centre for
Ecology & Hydrology



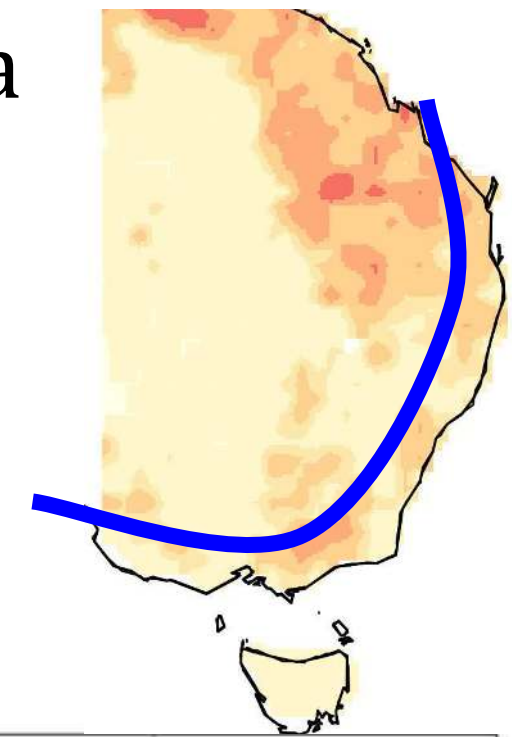
Problem 1: no high burnt areas - Sahel



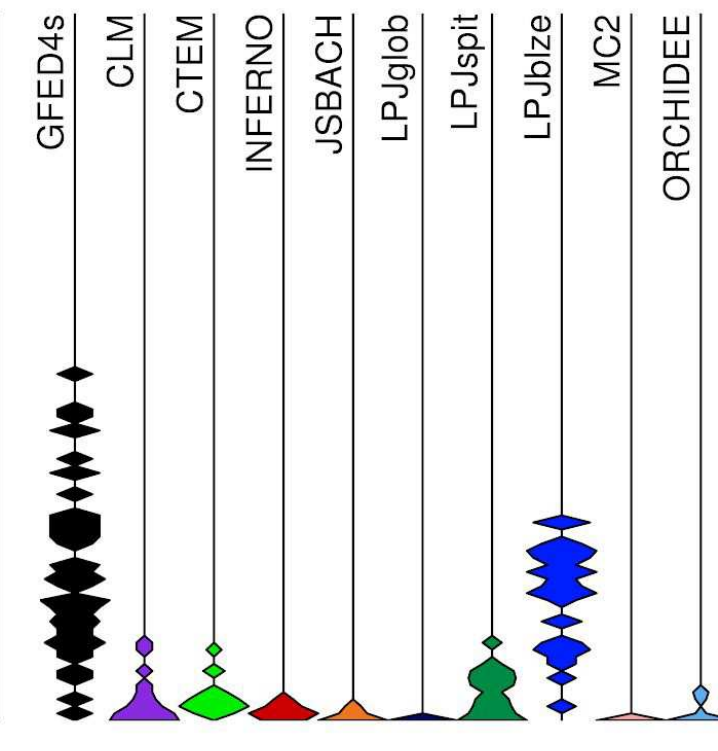
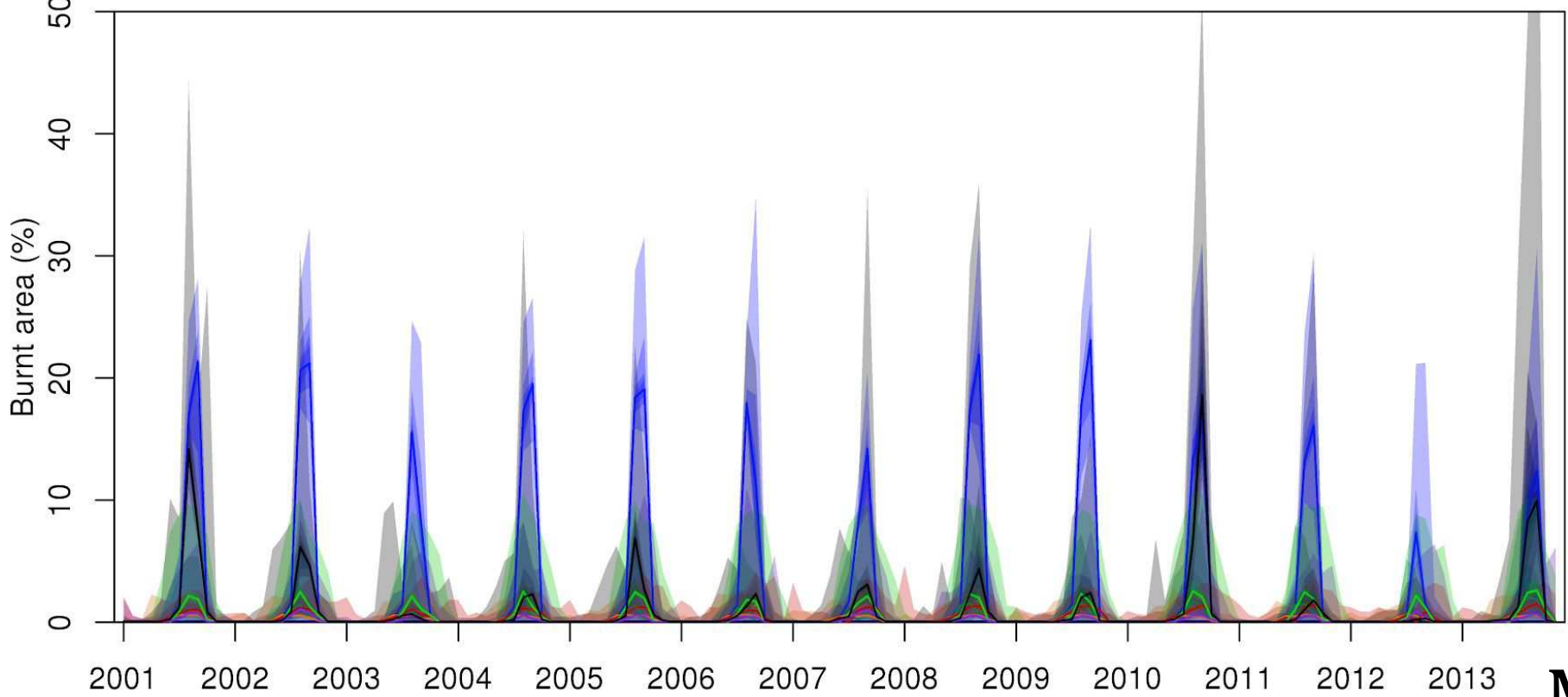
Problem 3: Inter-annual variability - South East Australia



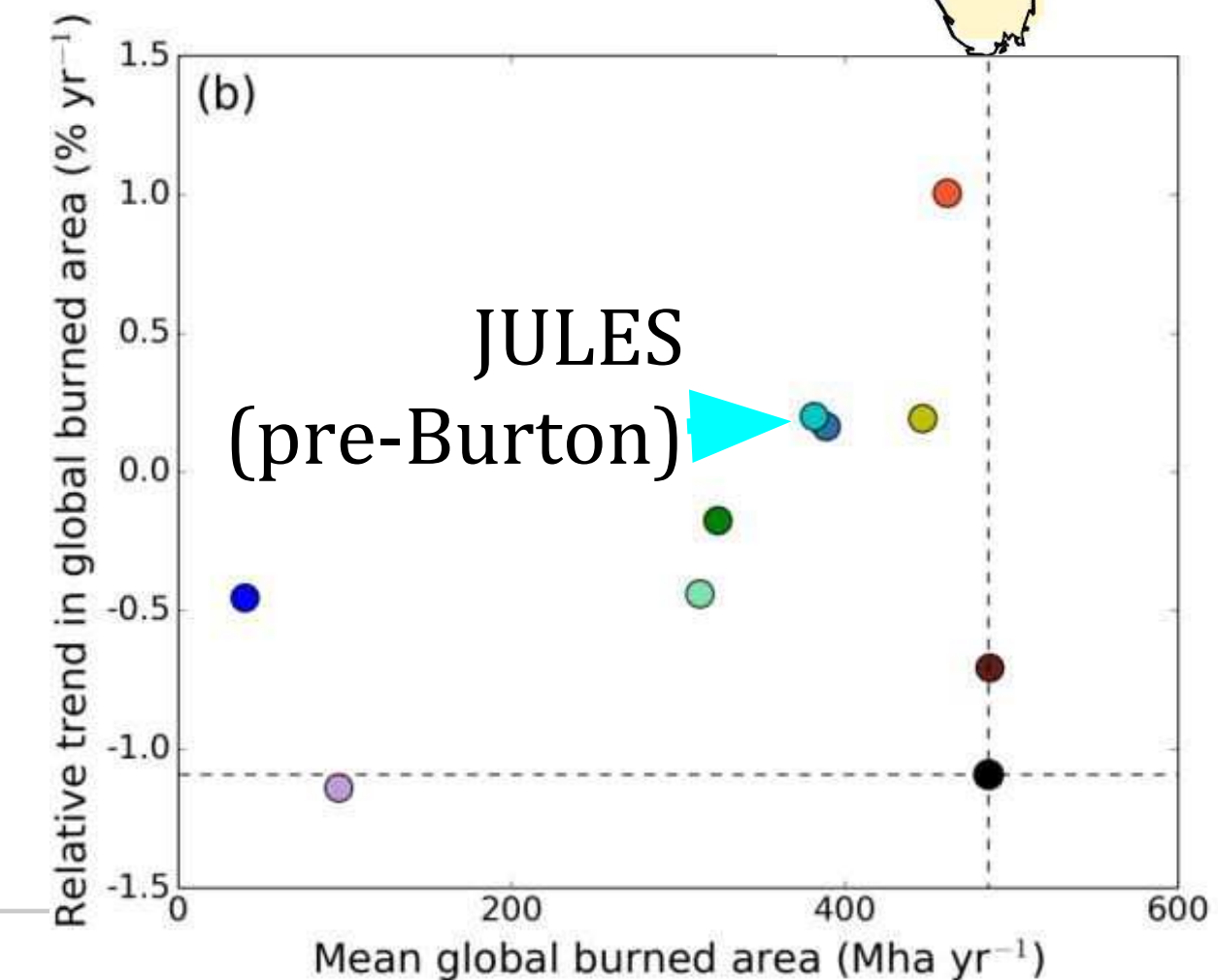
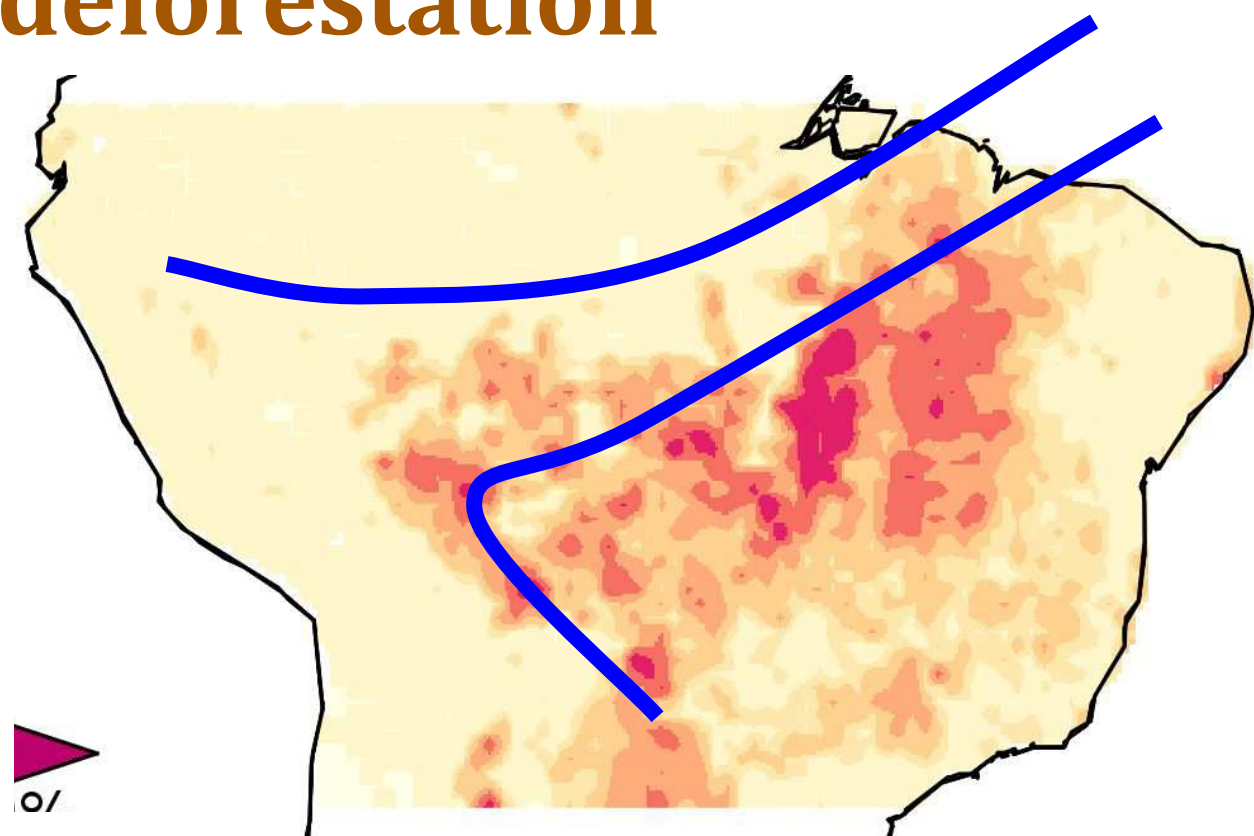
Max. Mnth burnt area



Problem 2: Human dominated fire regimes - Arc of deforestation



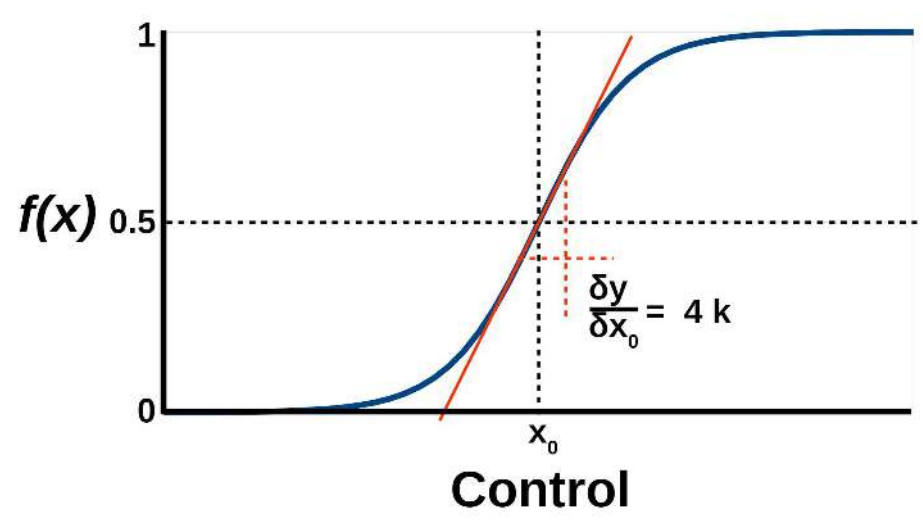
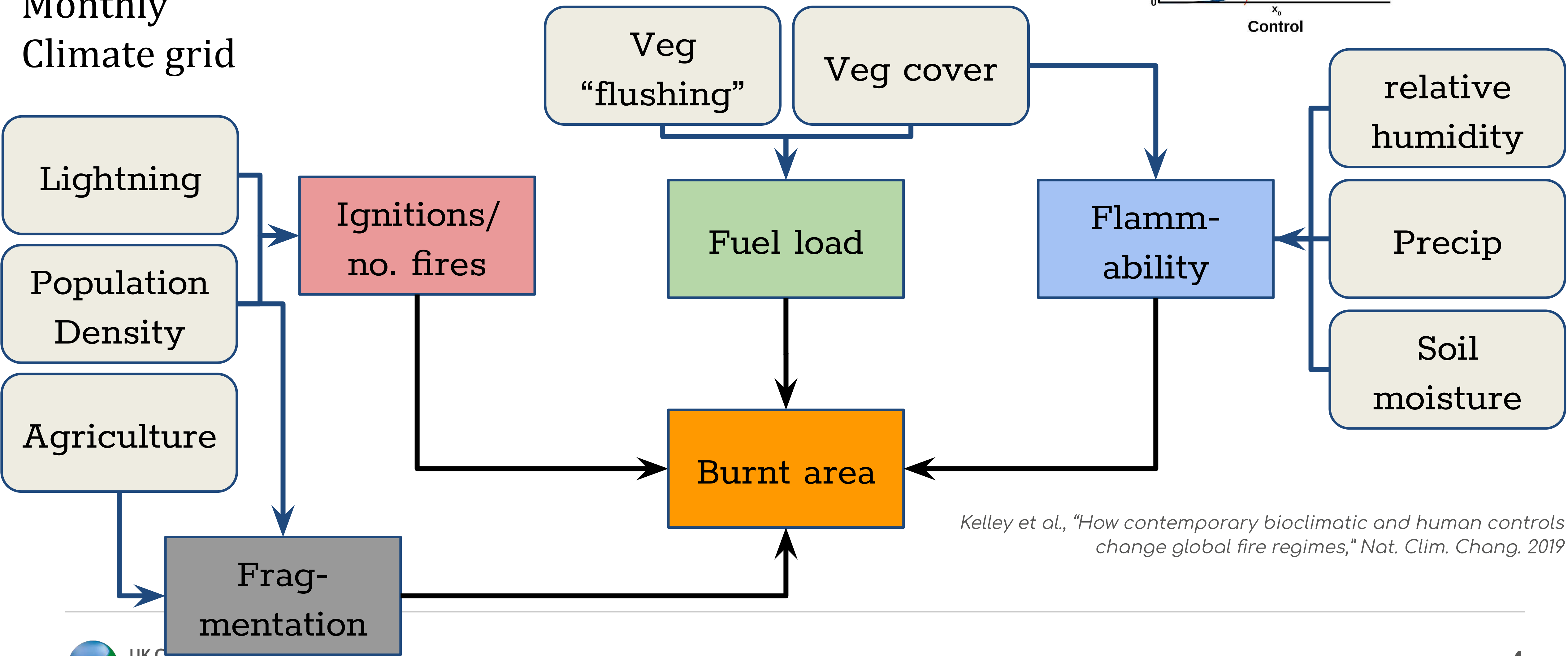
Max. Annual burnt area



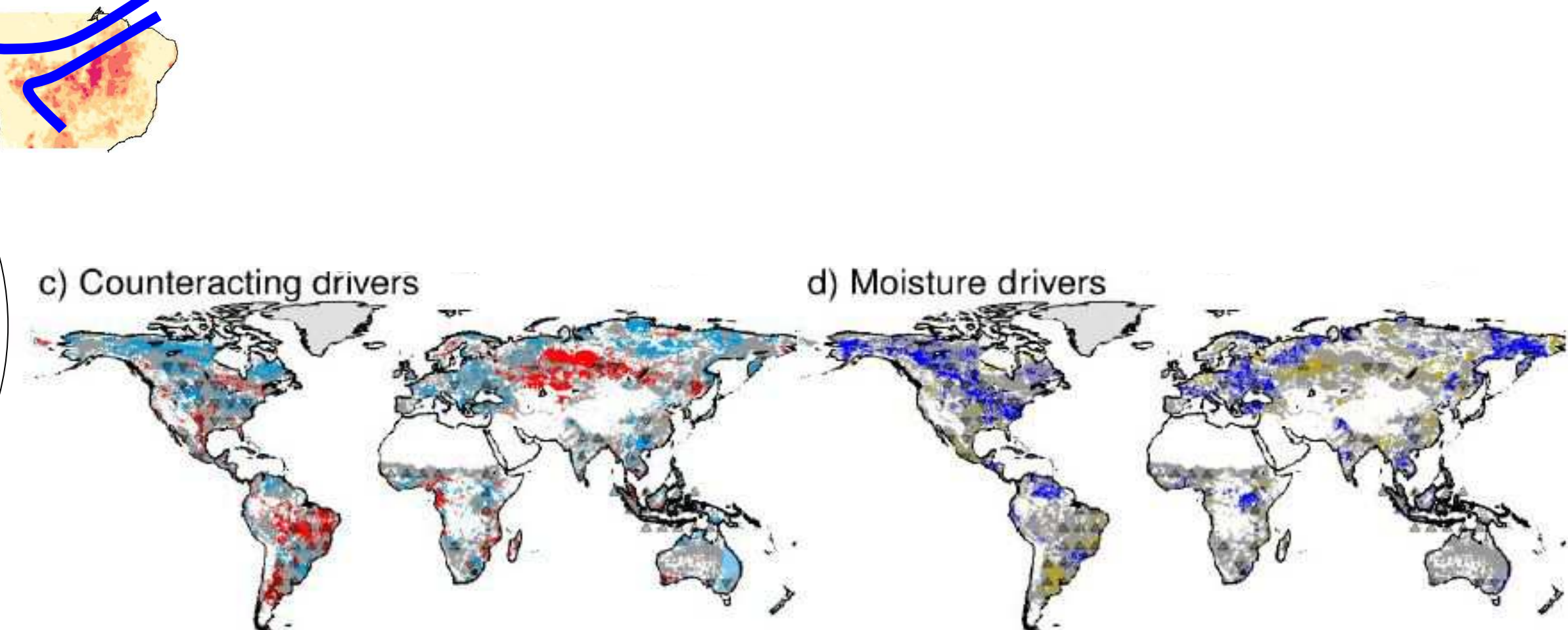
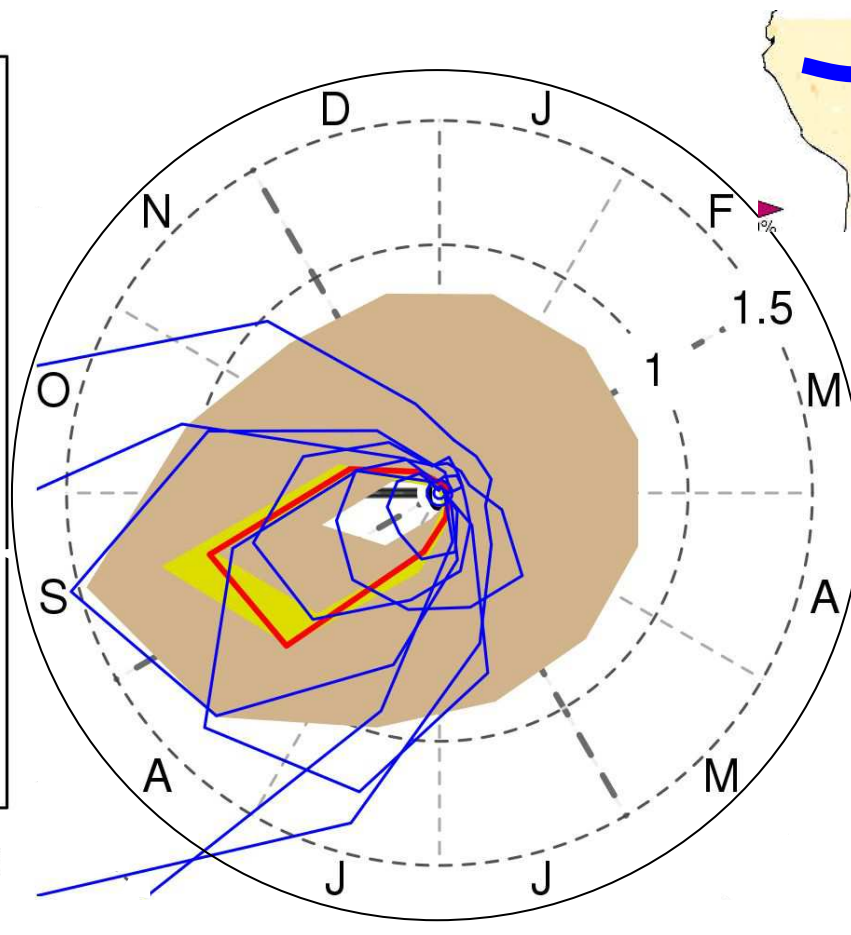
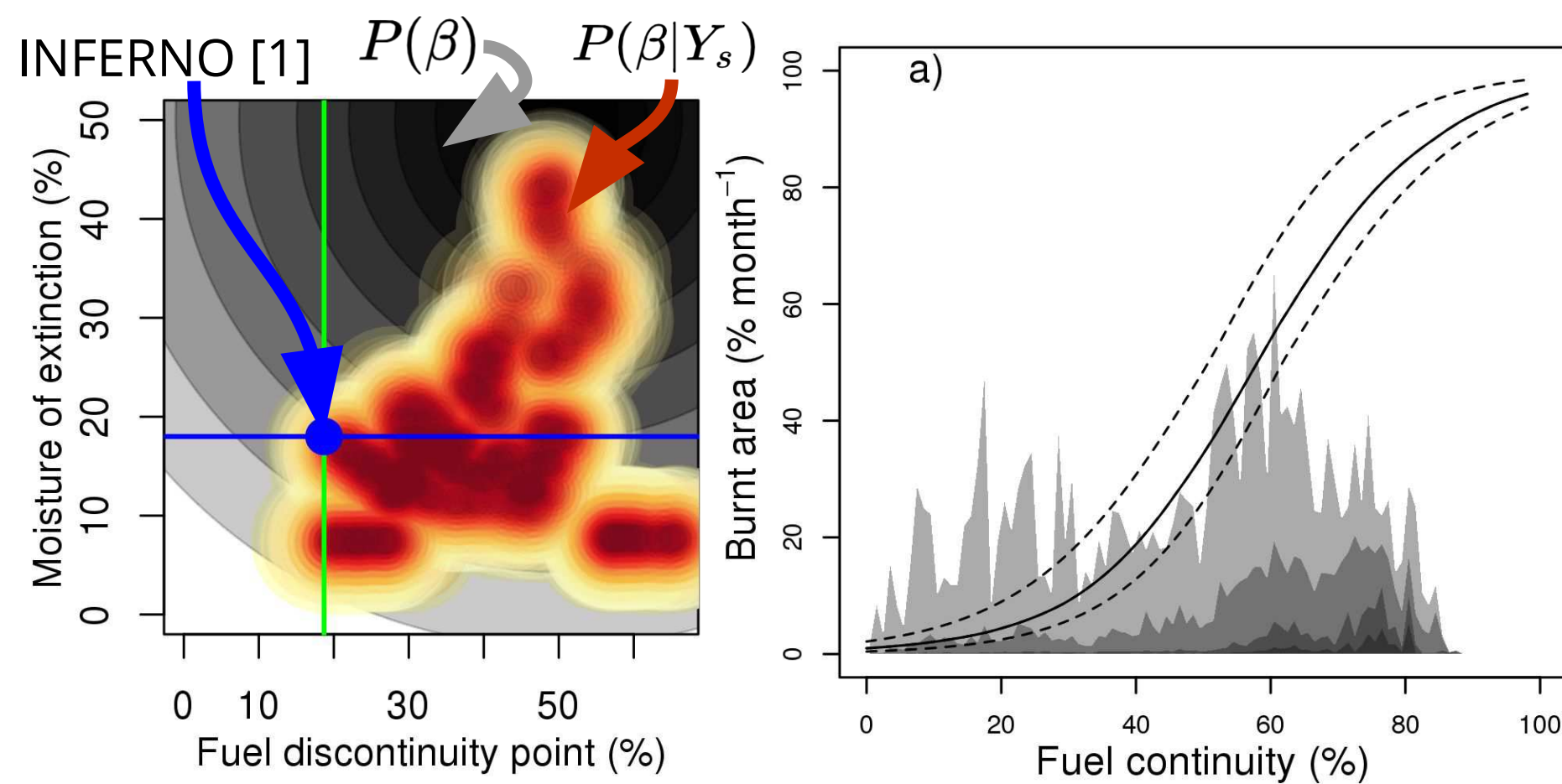
fireMIP priorities ...formal sensitivity and analysis on the input parameters to determine if fire models include correct processes/parameterisation should be prioritised to improve, and provide confidence in, model performance..... **(2018 workshop)**

“ConFIRE” - a skeleton fire model

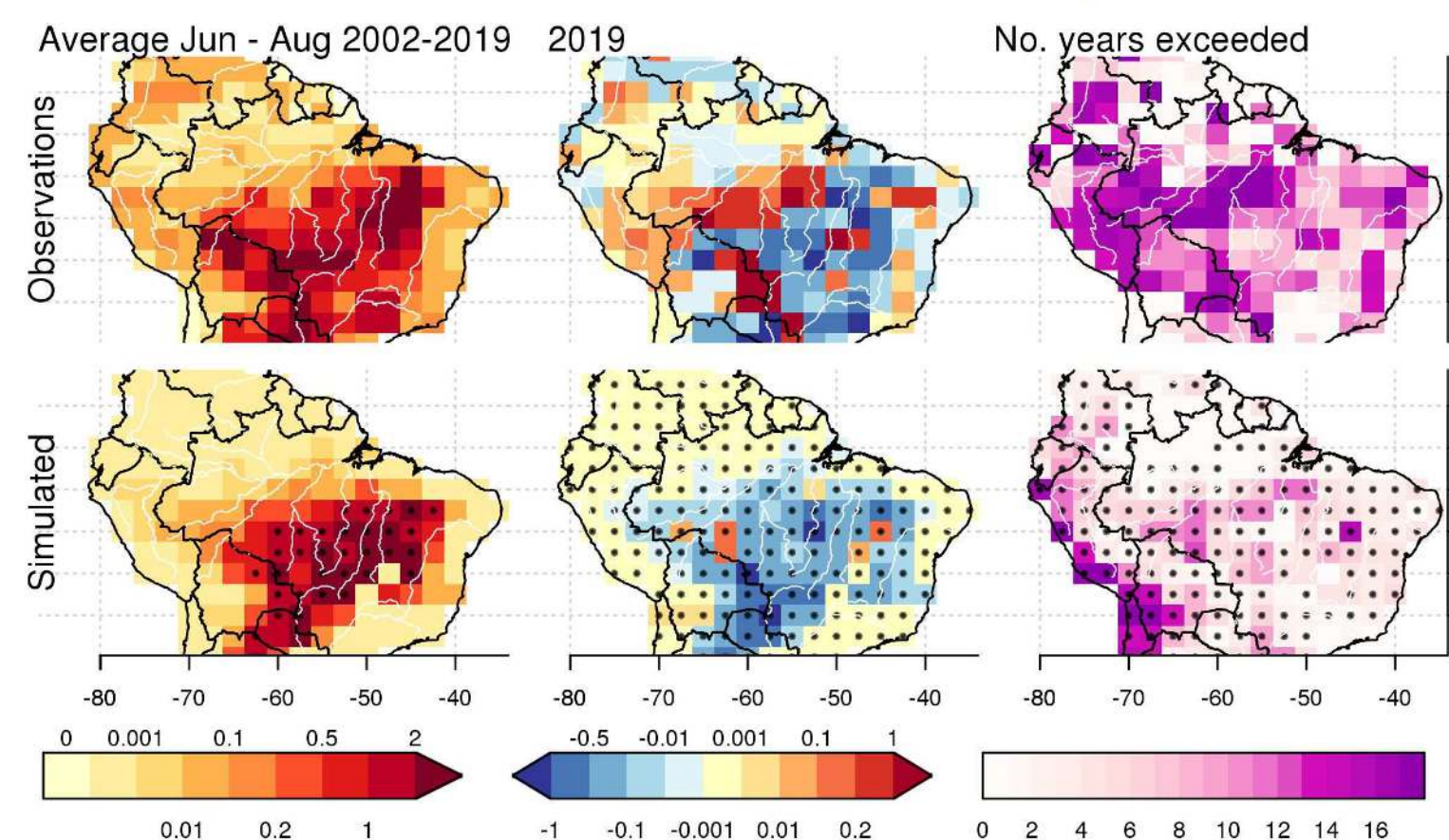
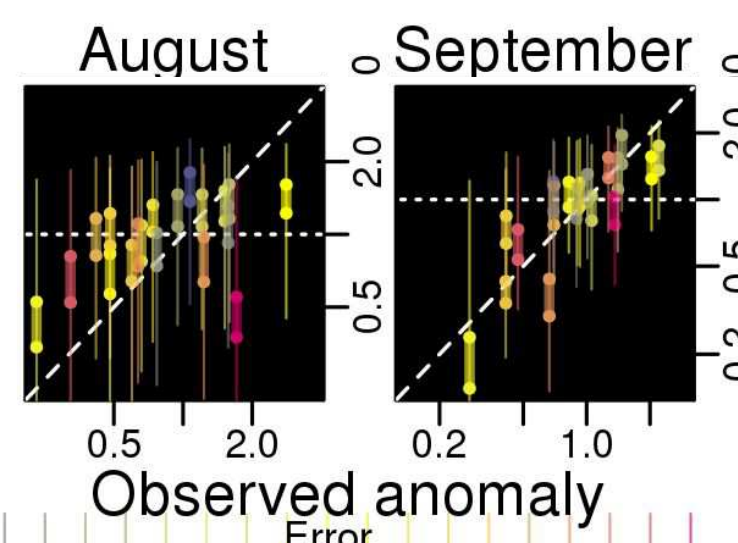
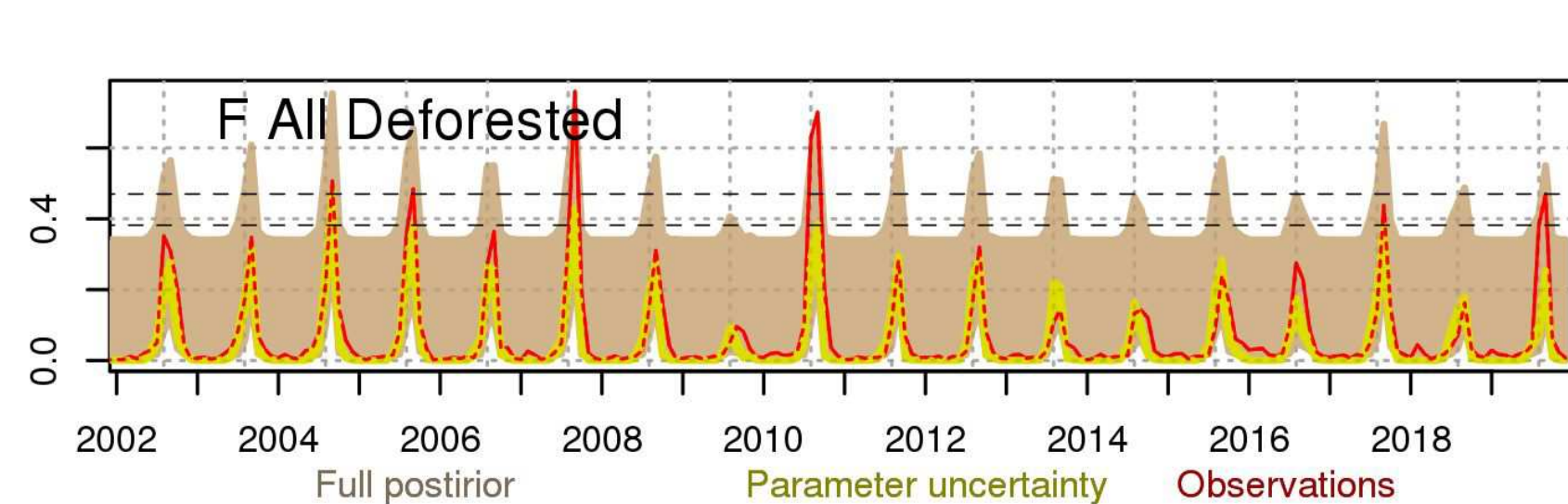
Monthly
Climate grid



Kelley et al., “How contemporary bioclimatic and human controls change global fire regimes,” Nat. Clim. Chang. 2019

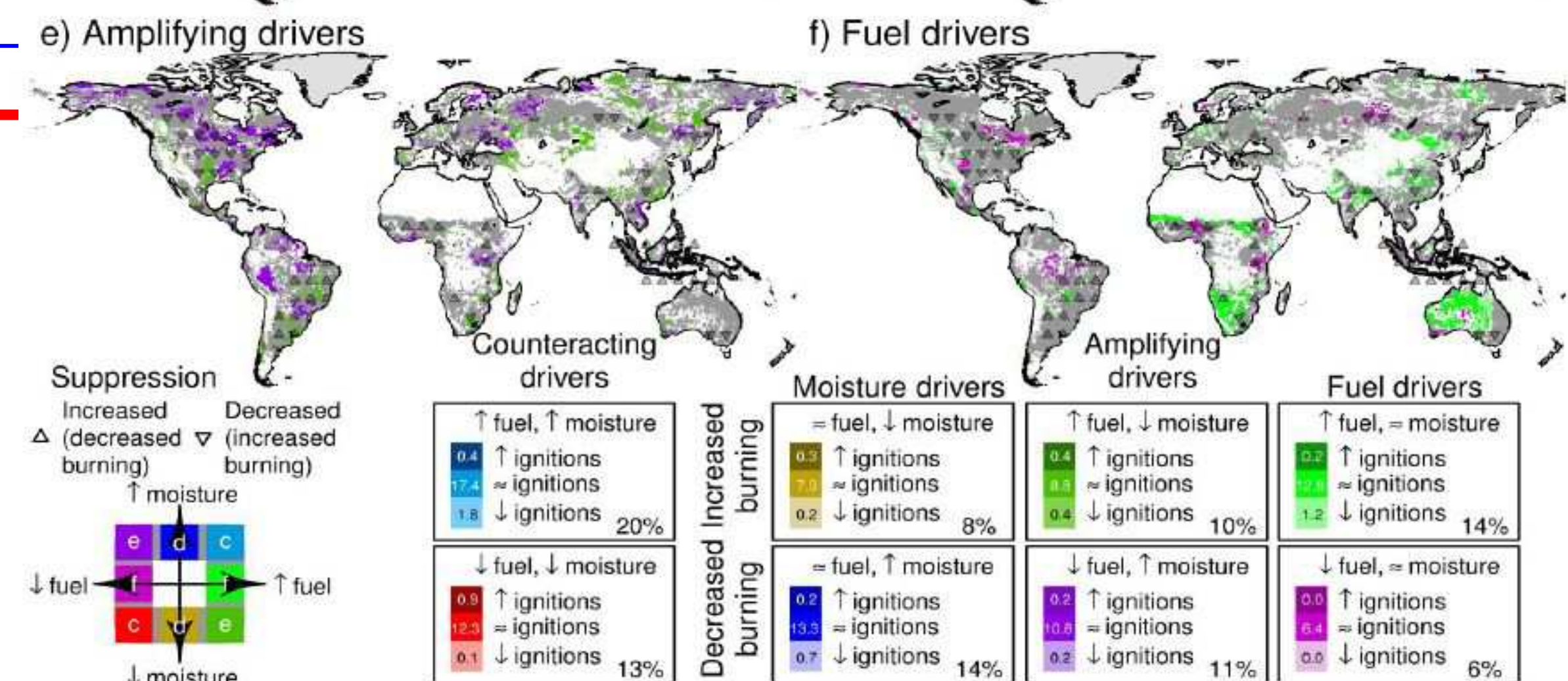


[1] converted from *Mangeon et al., GMD. 2016*
 see Bayesian example for conversion methods.
 [2] *Hantson et al., GMD discussions 2020*
 [3] *Giglio et al., "The Collection 6 MODIS burned area mapping algorithm and product," 2018*

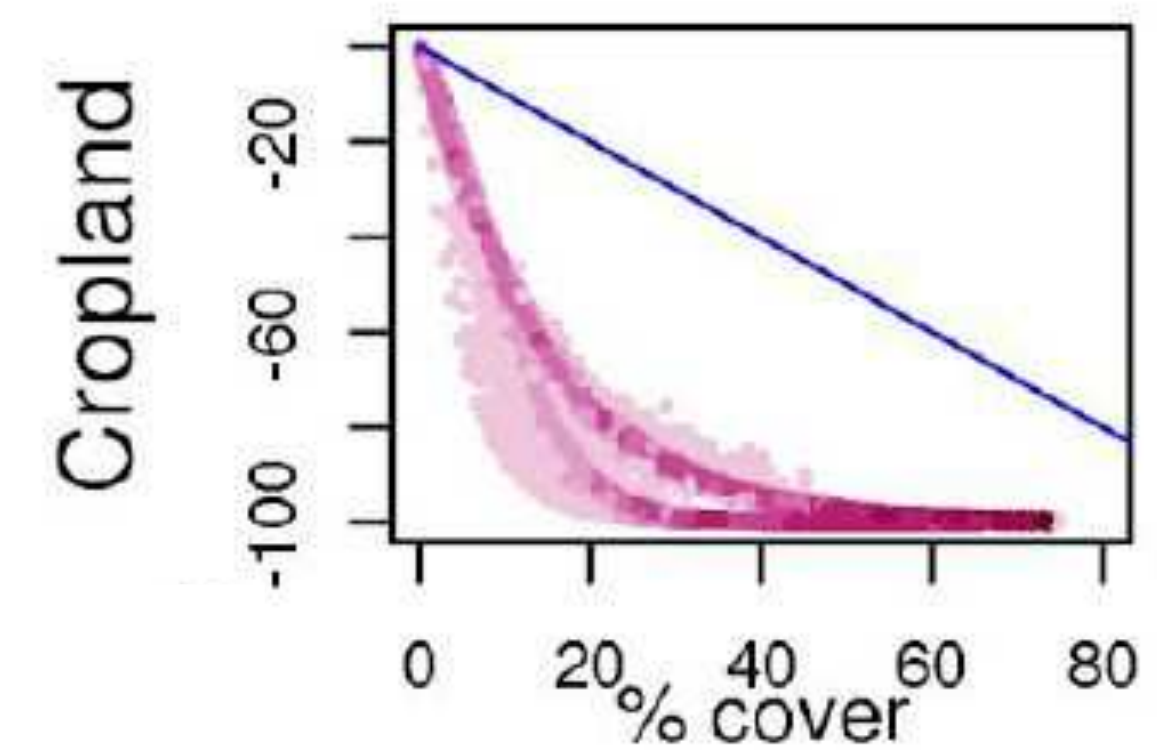


No meteorological influence found on Amazon burnt area in 2019

Kelley, et al., "Low meteorological influence found in 2019 Amazonia Fires" *Biogeosciences Discussion*, 2020



Kelley et al., "How contemporary bioclimatic and human controls change global fire regimes," *Nat. Clim. Chang.* 2019

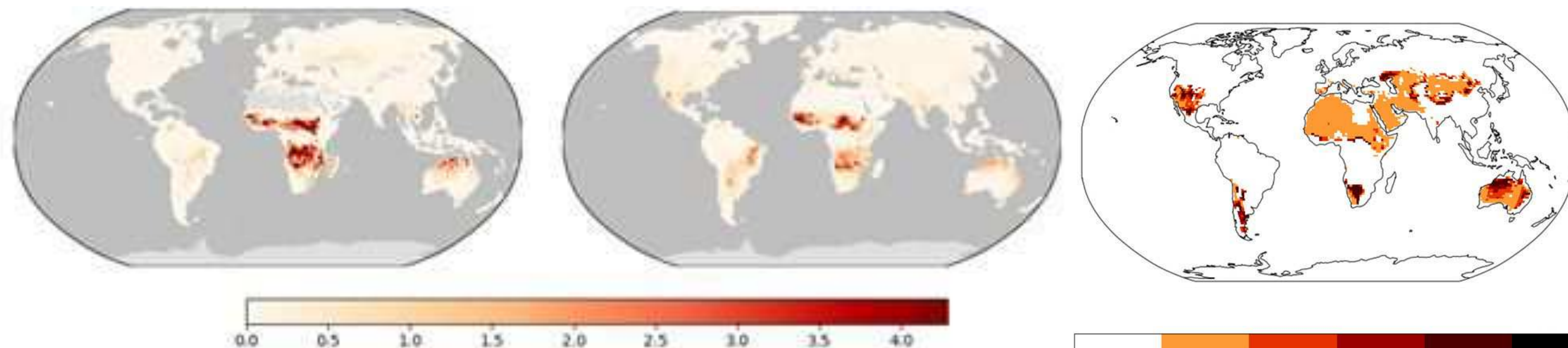
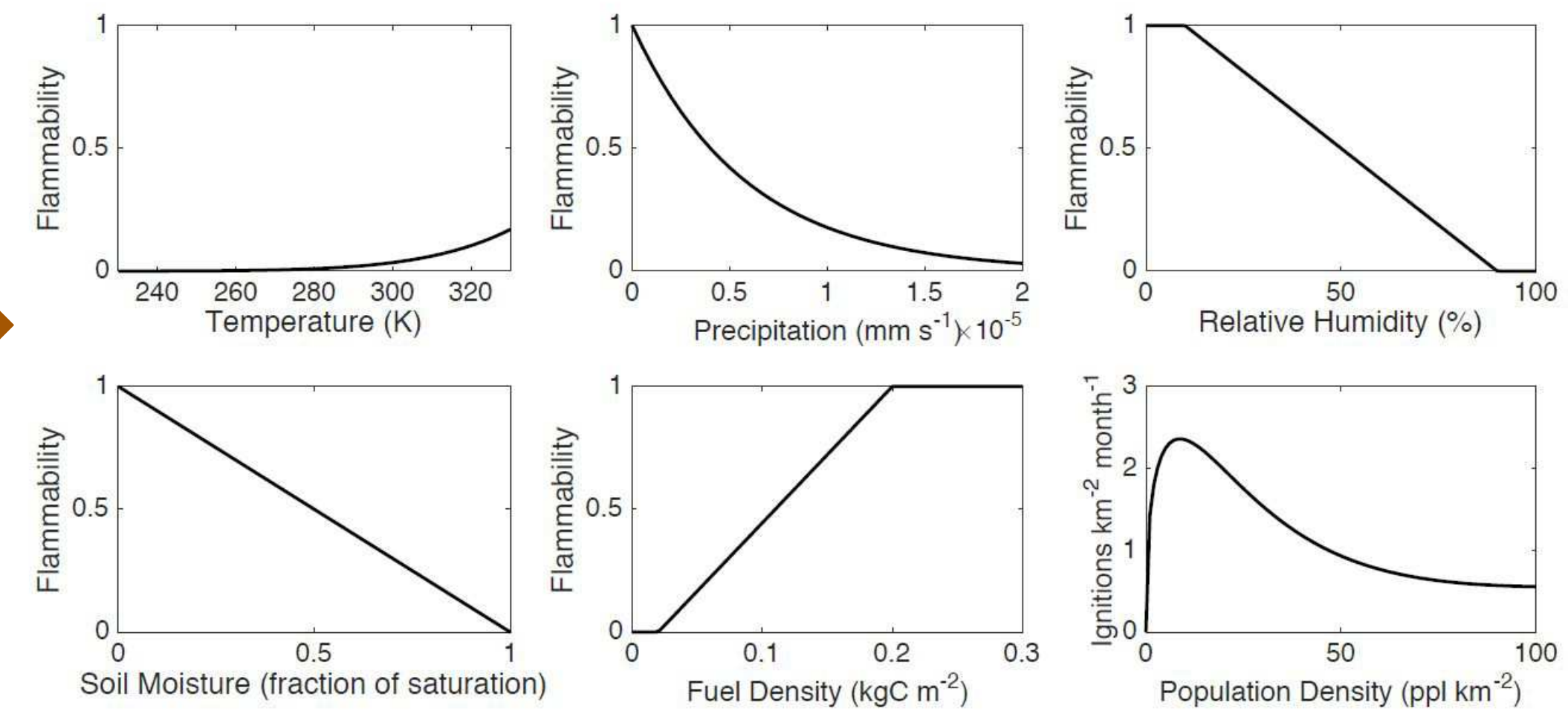
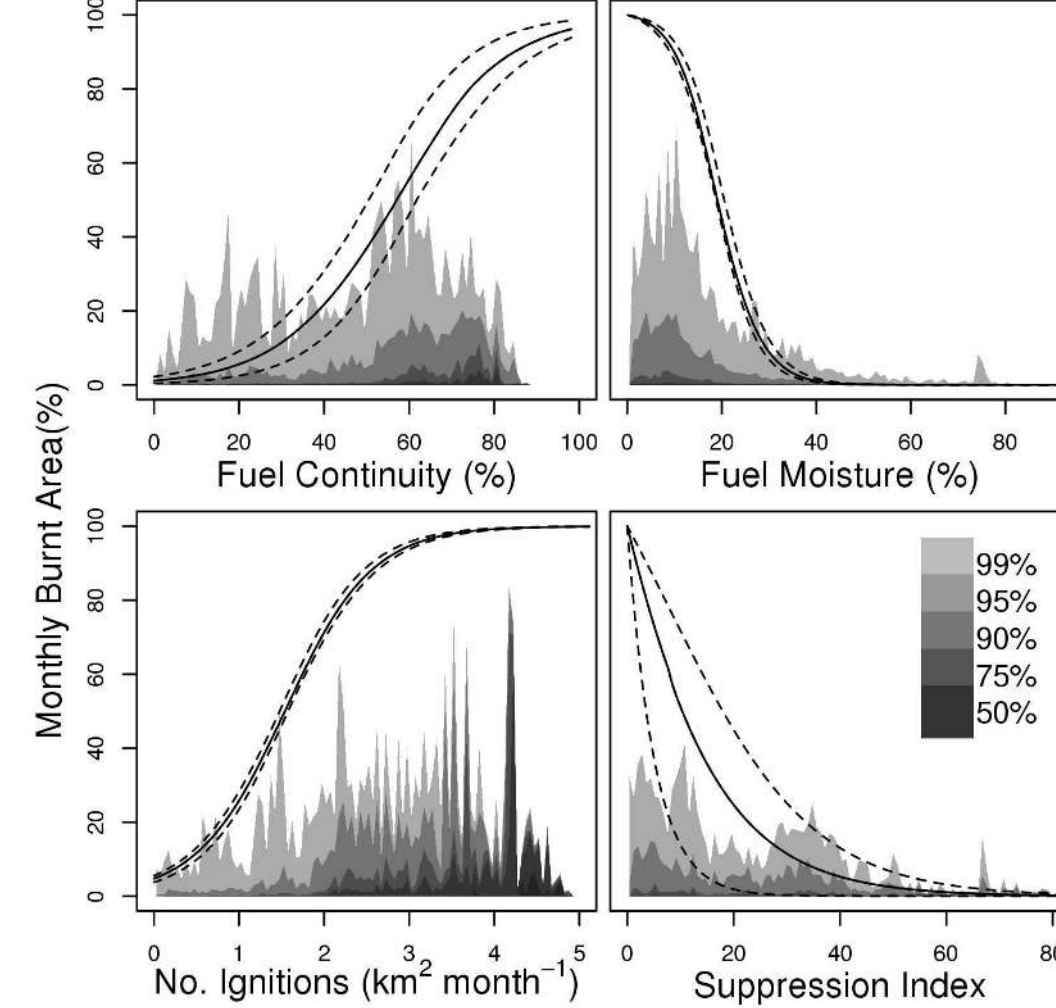


INFERNO-ise

- 6-hourly timestep - sampling 1 day a month
- Tile based fire size & fuel
- Get rid of “pointy” curves in INFERNO

ESM-ise

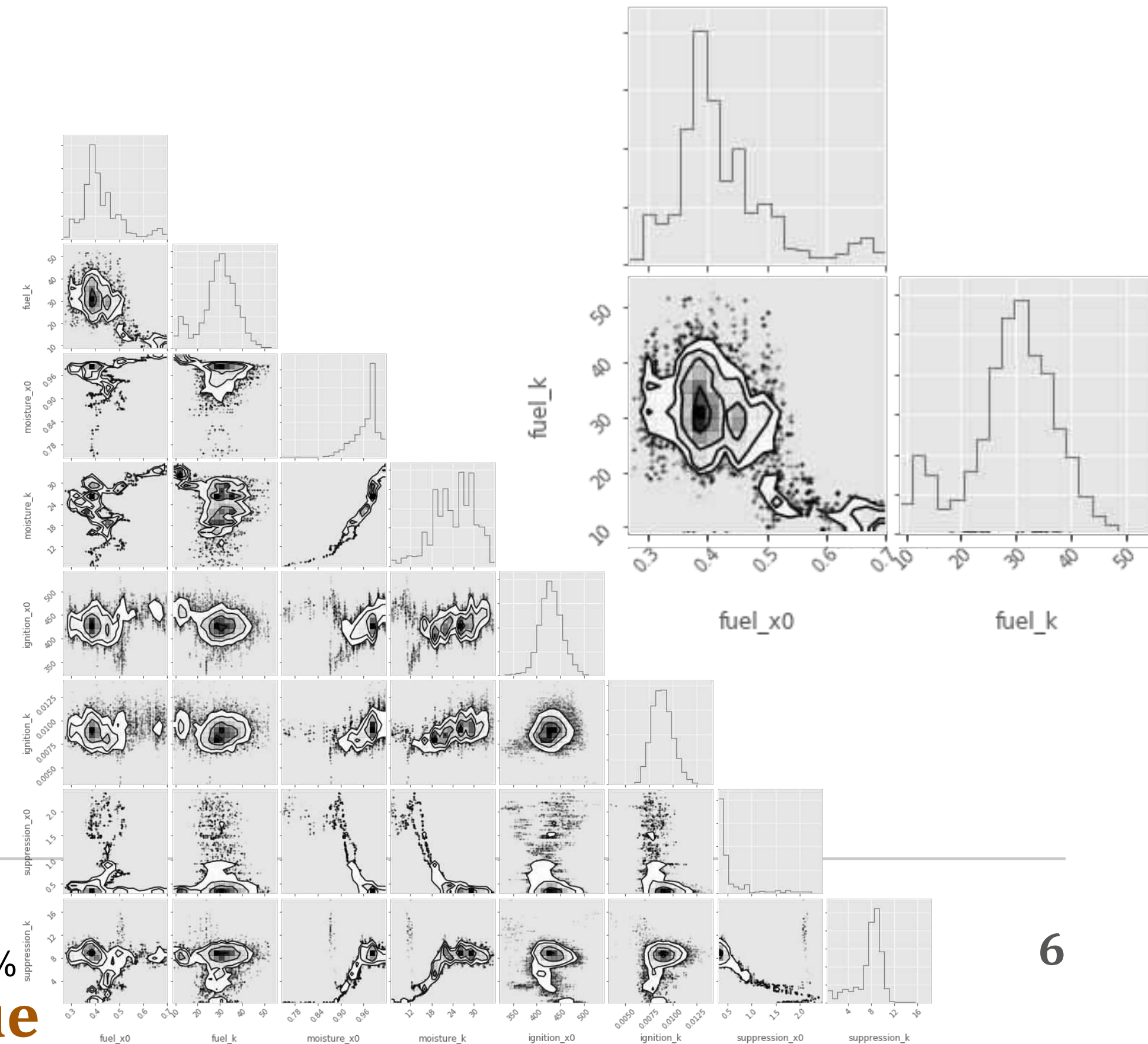
- Single or small number parameter selection
- Parameter selection under climate/veg biases
- None-fire applications?



GFED4s Obs

Current approach
(stolen from Chantelle)

“Best” parameter value



Done!

Any questions?



See github.com/douglask3/amazon_fires/tree/EGU2020
or use QR code for to run Bayesian modelling framework



UK Centre for
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