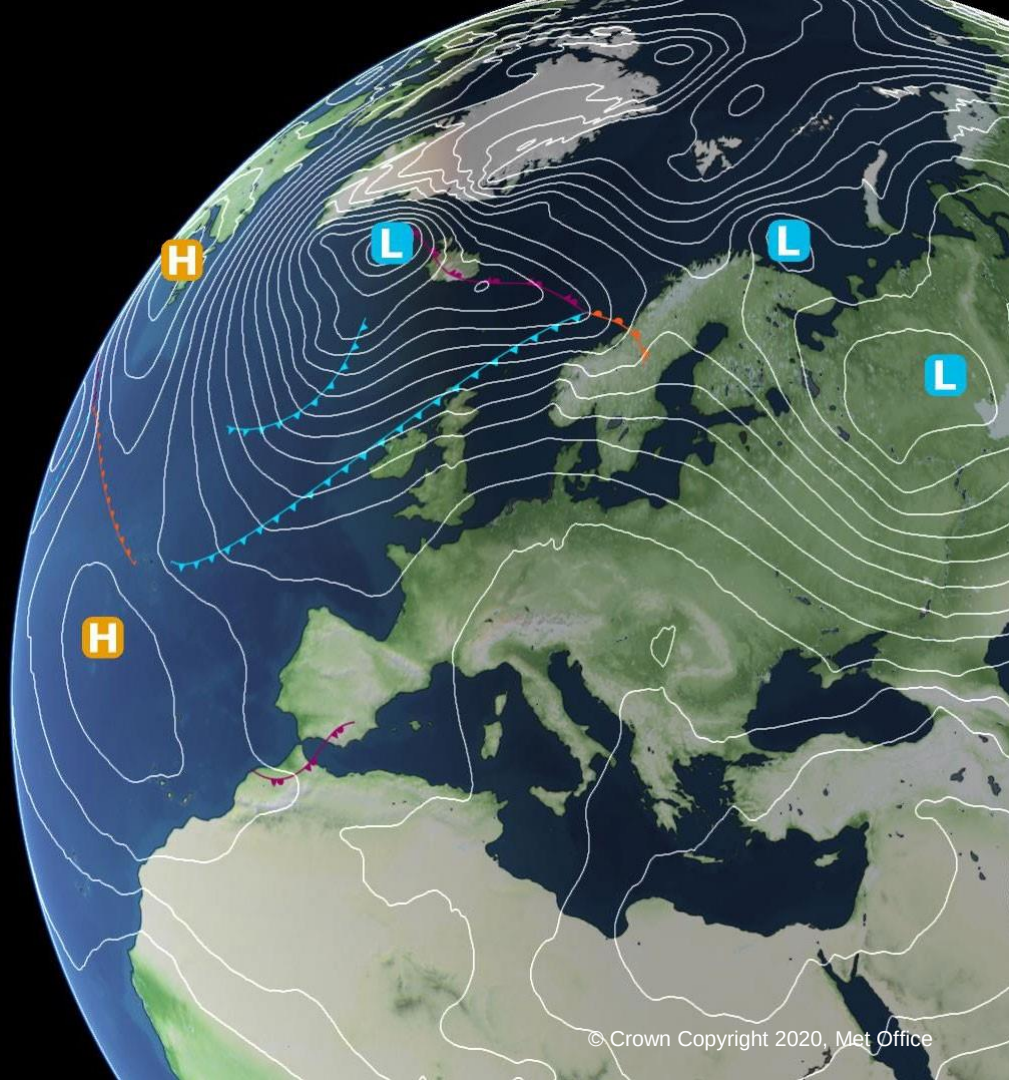
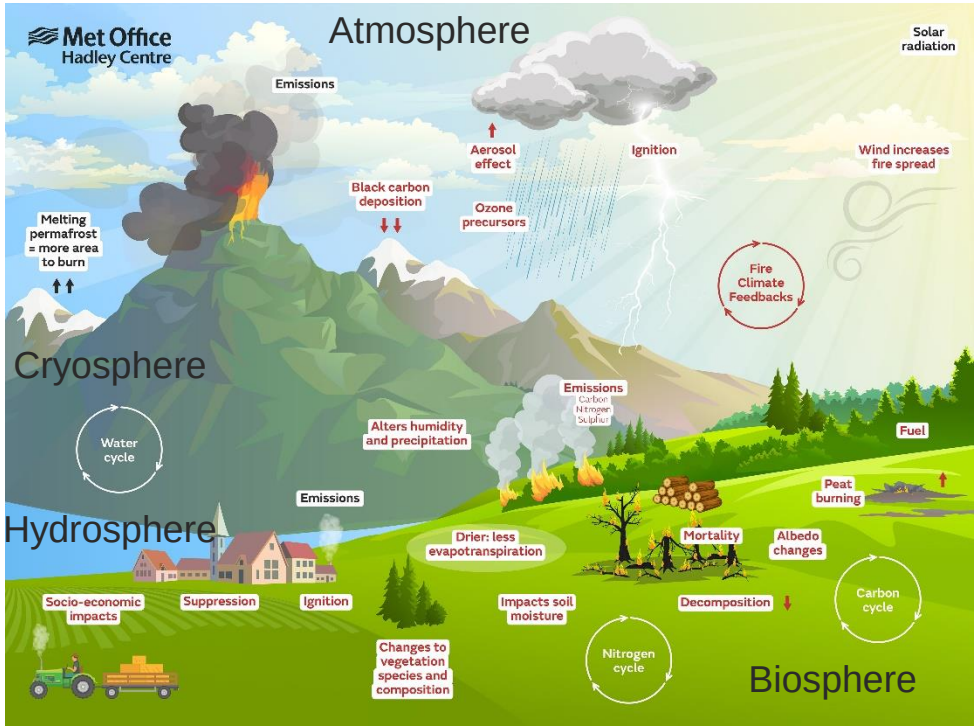
Met Office
Hadley Centre

Fire in UKESM

Chantelle Burton, João Teixeira, Doug Kelley, Gerd Folberth, Andy Wiltshire



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

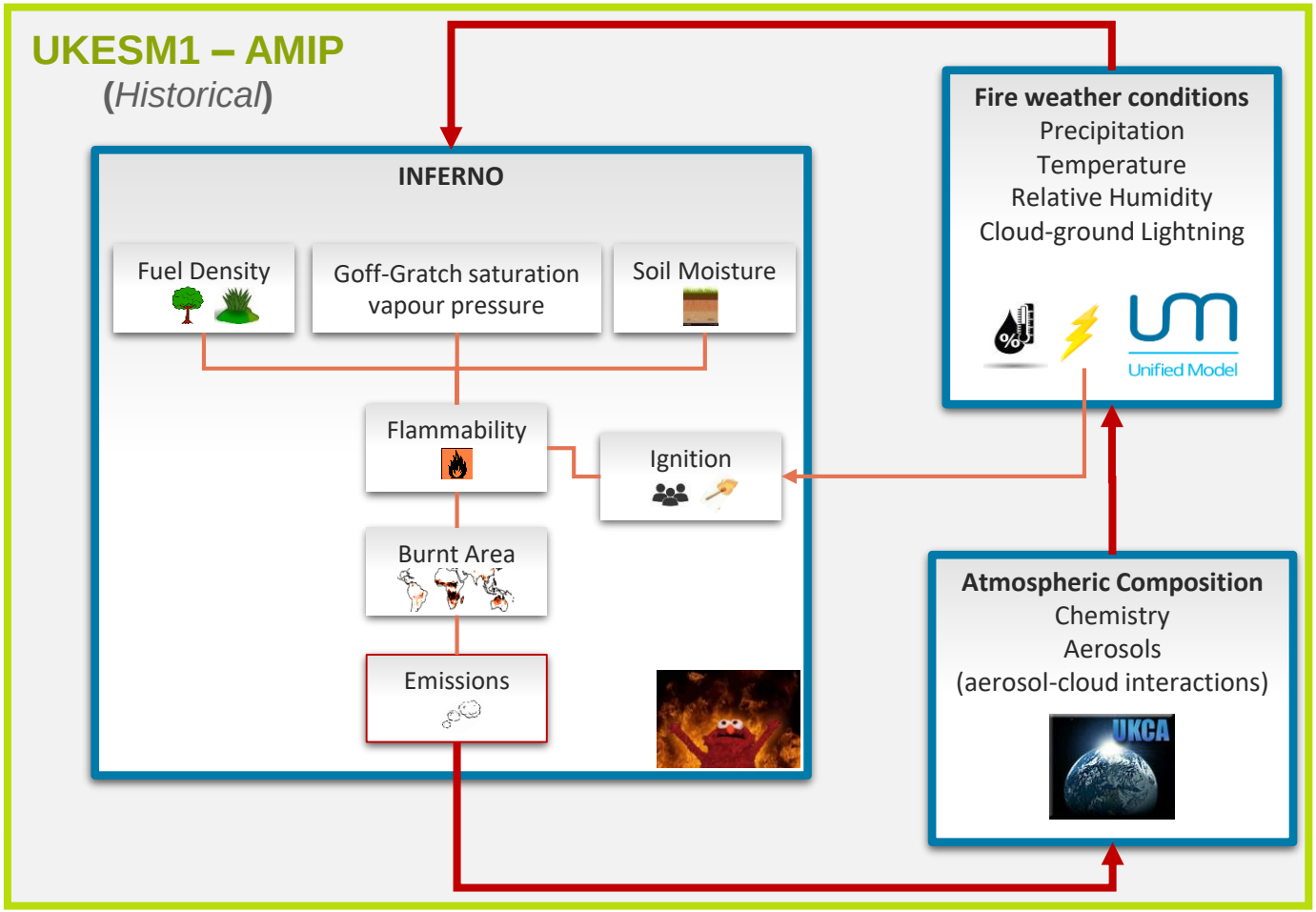


- Largest source of carbonaceous aerosol globally
  - ~ 60 % of the of primary OC and BC aerosol emissions
  - Dominant source for central Africa and Amazon regions
- Total net negative radiative effect of -1.02 W m^{-2} pre-industrial period (1850) (Ward et al. 2012)
- Low agreement on the regional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

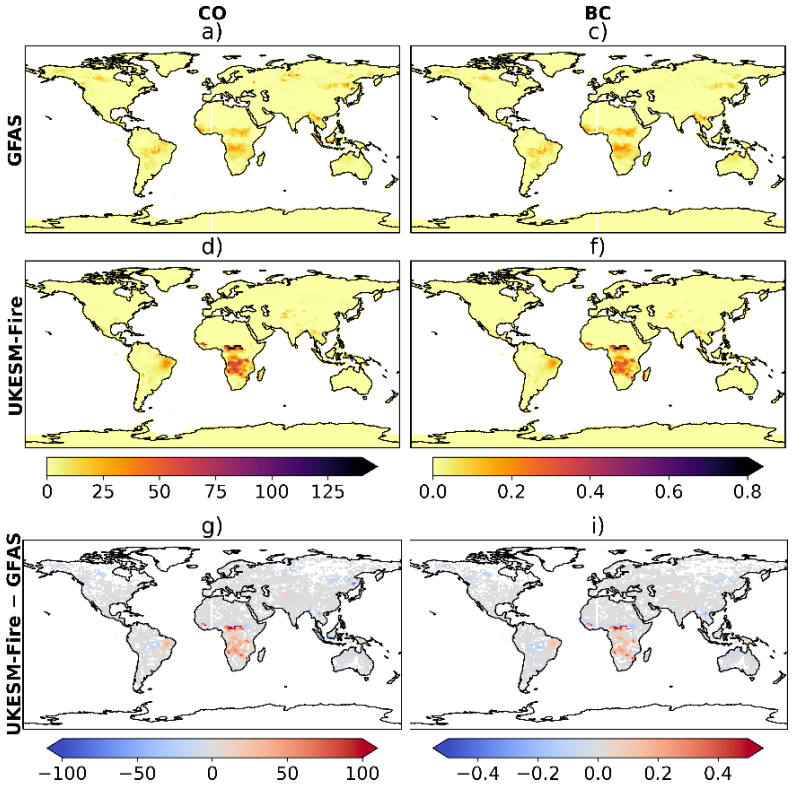
Total radiative effect of fires remains uncertain making climate-fire feedbacks relevant in the context of climate change research

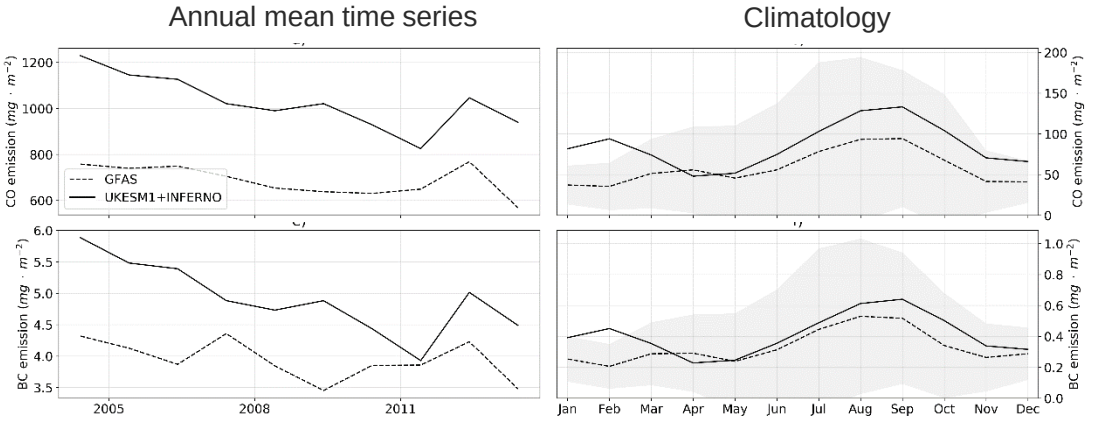
Objective → **Development and evaluation** of a coupled fire-composition-climate Earth system model

Coupling framework



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

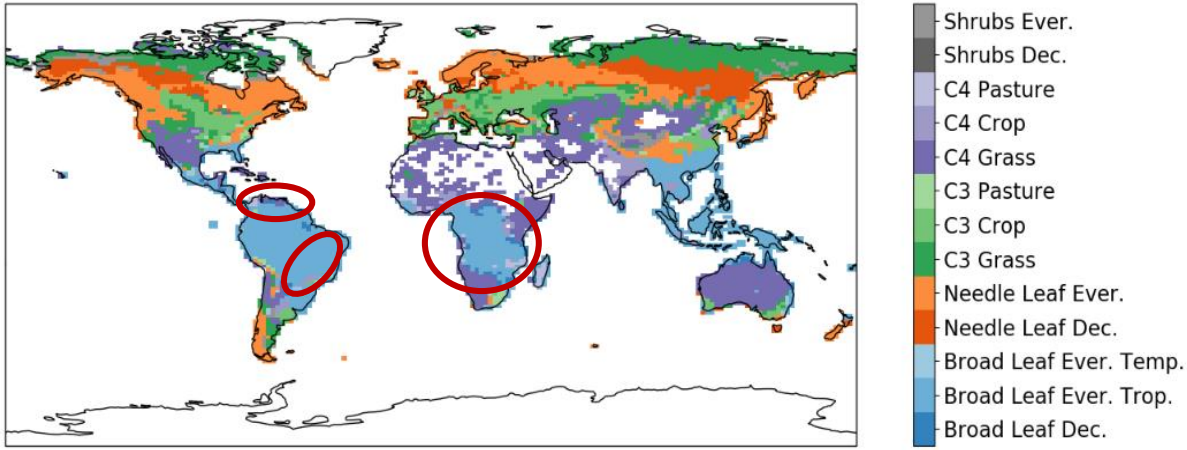




- Global pattern well reproduced
- Large overestimation of the biomass burning emissions
  - NHAF
  - SHAF – emissions extend further south
  - SHSA – large bias on the eastern edge
- Underestimation over the peatland regions
  (e.g. Indonesia and boreal regions)
- Seasonal cycle well reproduced – partially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

What drives the NHAF and SHAF bias?

Dominant vegetation Plant Functional Type (PFT)
prescribed from UKESM1 Historical



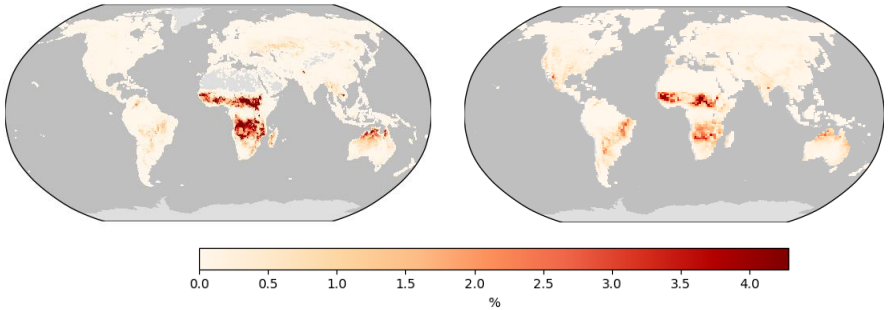
Bias in underlying vegetation

Overestimation of tree fraction in savanna biomes impacts the fire model:

- Underestimation of burnt area
- Overestimation of biomass burning emissions

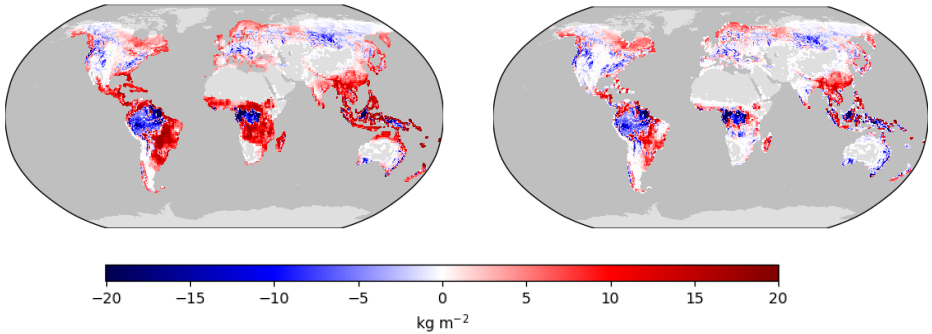
Offline runs (JULES-ES)

GFED4s (observations) JULES-ES

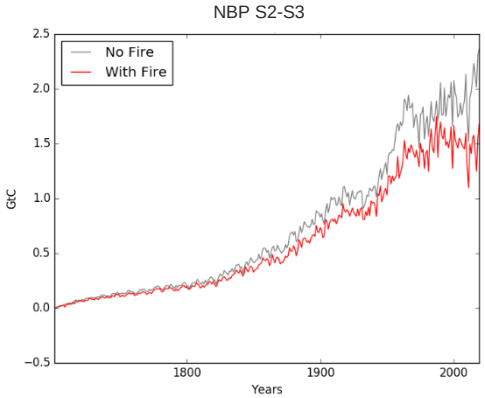


Monthly percentage burned area

No Fire With Fire



Bias in vegetation carbon (compared to GEOCARBON)



Net Biome Productivity

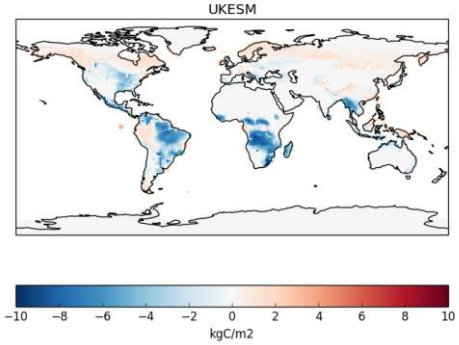
Present day:
No fire = 2.0 GtC
With fire = 1.5 GtC
GCP estimate as a residual of other carbon fluxes = 2.1+/-0.7
TRENDY models = 1.0 +/- 0.8
2009-2018

S2 = no land use change
S3 = with land use change

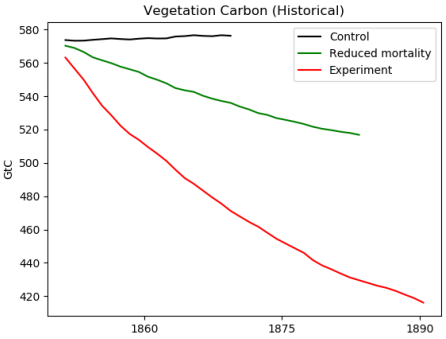
Variable	Obs estimates	JULES-ES	JULES-ES +fire
Vegetation Carbon	~460 GtC (IPCC AR5)	~630 GtC	~445 GtC
NPP	~55 GtC	~78 GtC	~70 GtC
GPP	~100-130 GtC	~150 GtC	~130 GtC

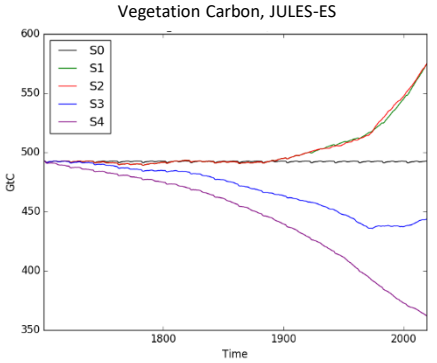
Fully coupled UKESM runs with fire

- 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



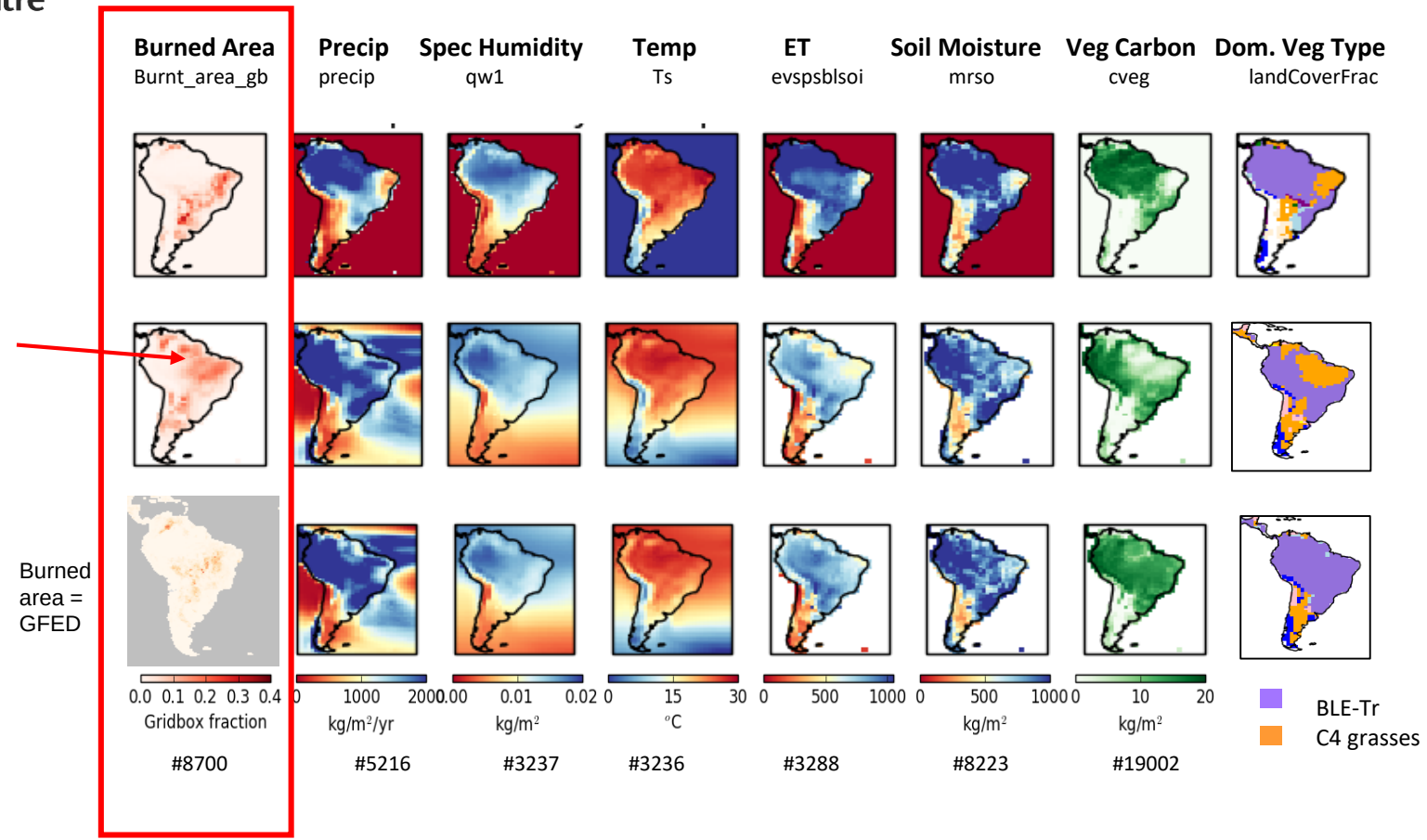
Change in veg carbon from 1860s to 1960s in UKESM historical run (top) and change from JULES-ES NoFire to Fire (bottom)





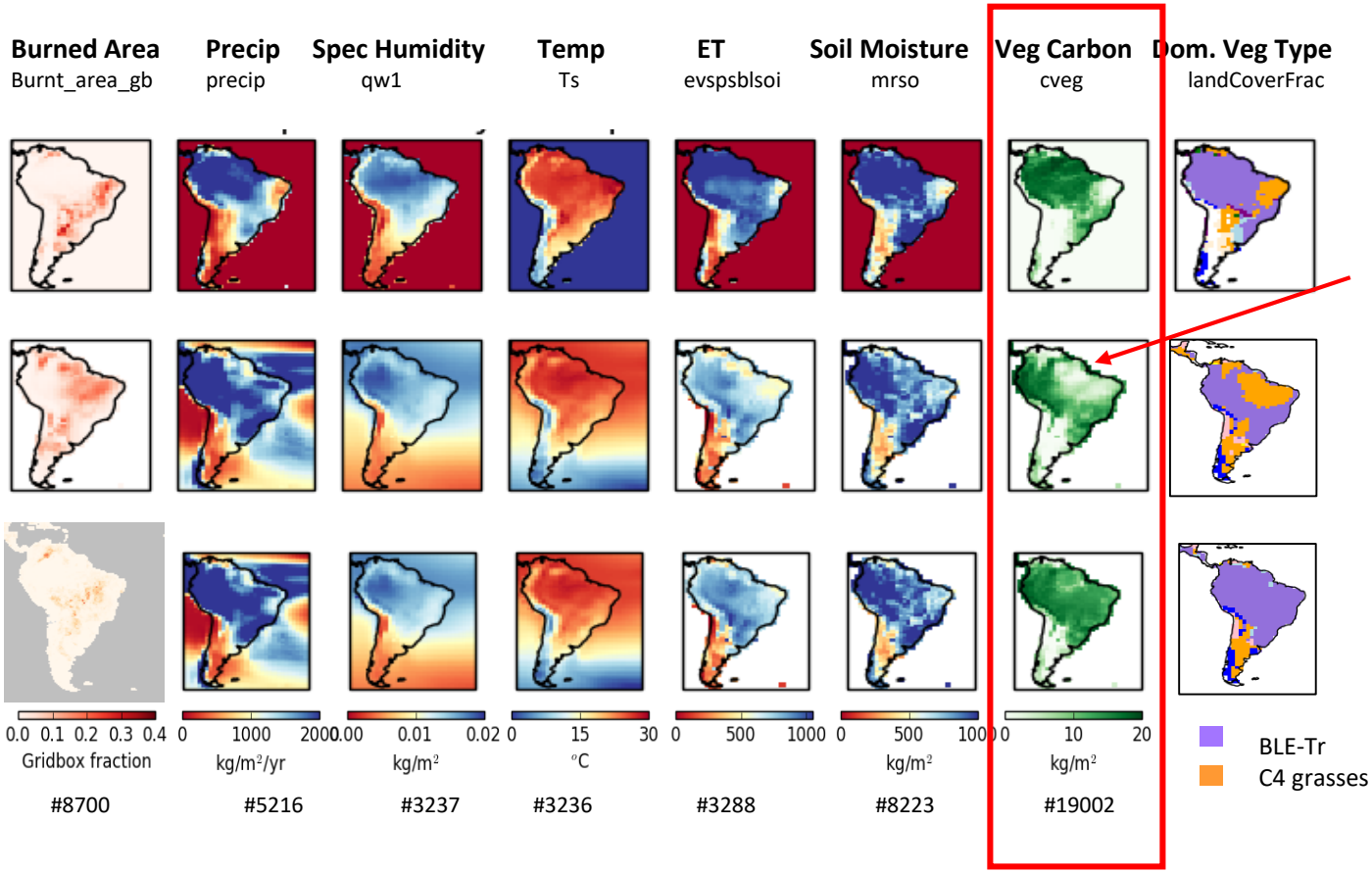
S3 (blue)= with land use change

Some problems over South America



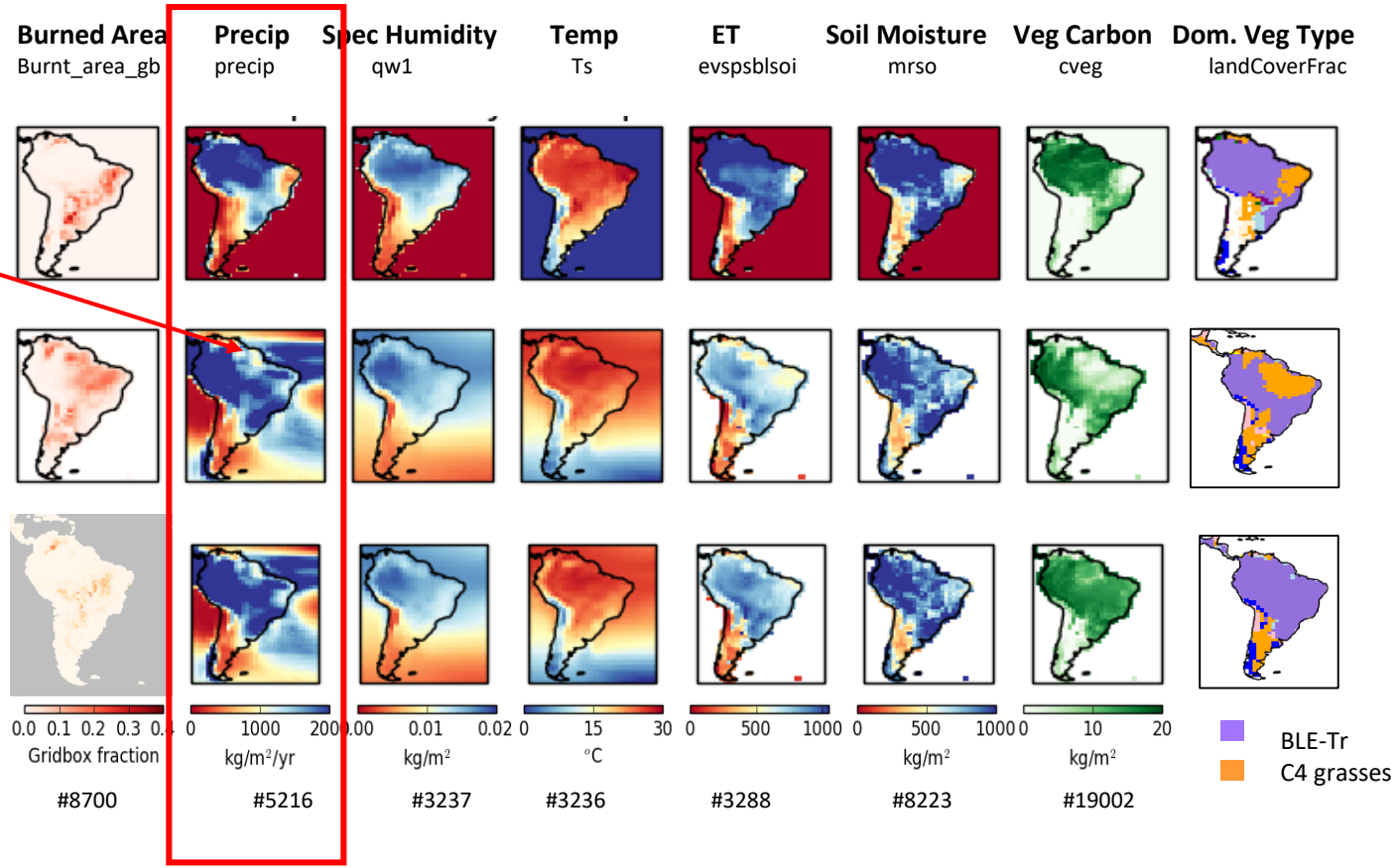
Historical 1930-1960 mean

Some problems over South America



Historical 1930-1960 mean

Some problems over South America

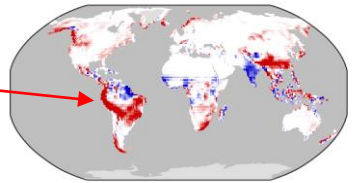


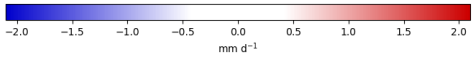
Historical 1930-1960 mean

Some problems over South America (work in progress)

Precipitation in UKESM

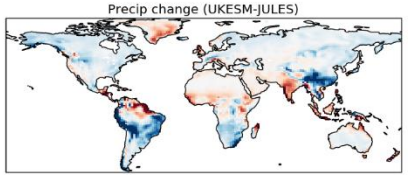
Dry bias already in UKESM…

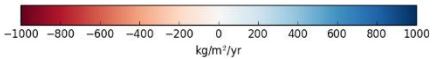




UKESM bias against CMAP (ilamb)
(reversed colour scale)

UKESM bias (no fire)

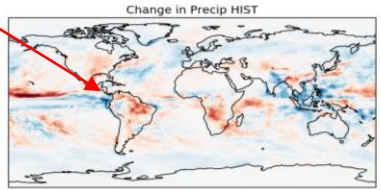


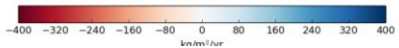


UKESM bias against JULES offline (UKESM1-JULES)
30 year mean (1970-2000)
PI control UKESM – JULES

… & fire makes this worse for precip and veg carbon

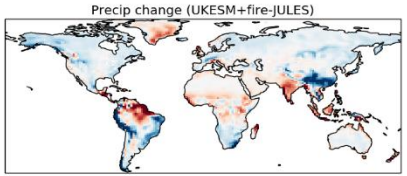
But may improve veg carbon in other areas, once tuned… needs more work to explore this

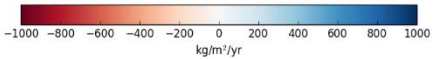




Impact of fire on precip (UKESMfire-UKESM1)
30 year mean (1930-1960)
HIST+fire – HIST CTRL

Fire impacts





Impact of fire compared to JULES (UKESMfire-JULESfire)
30 year mean (1970-2000)
PI control (bs209)+ fire – JULES