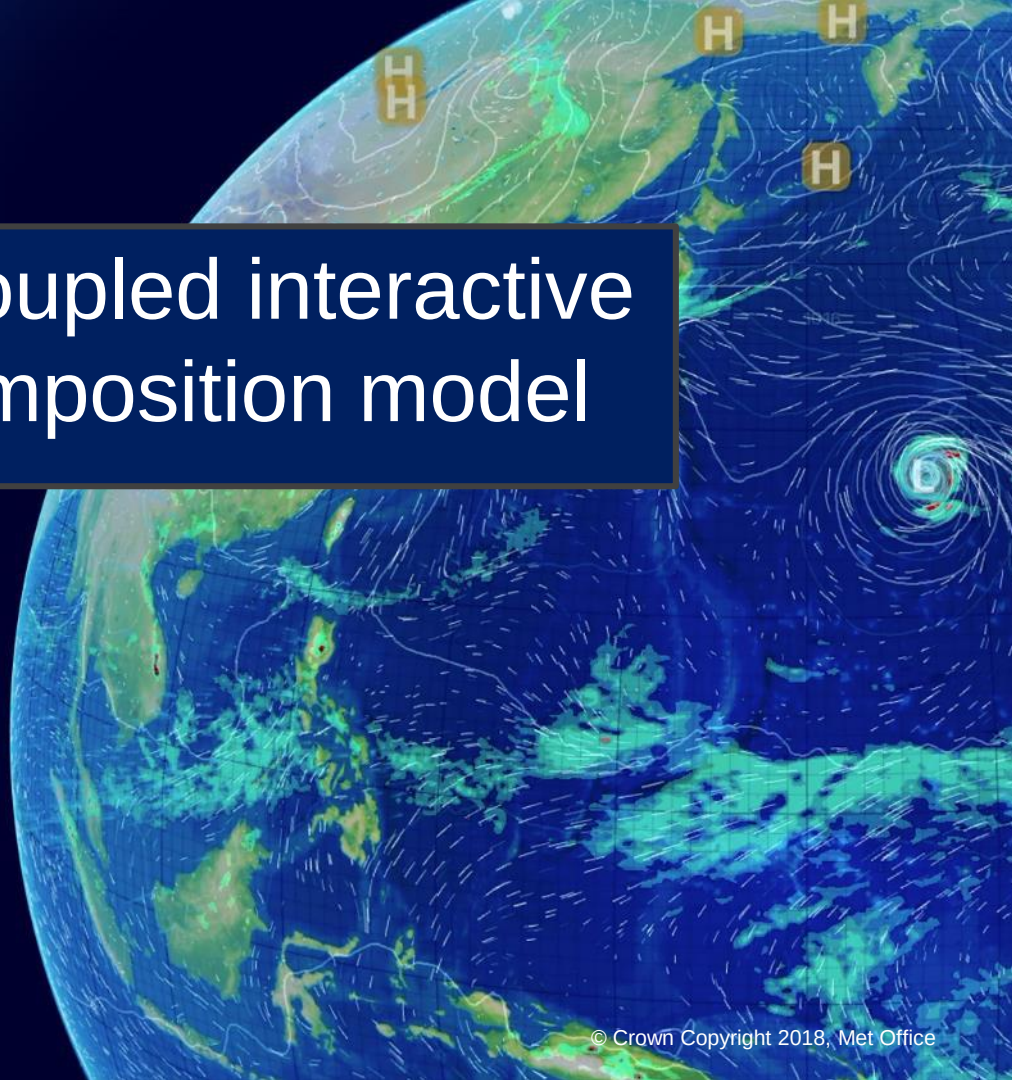
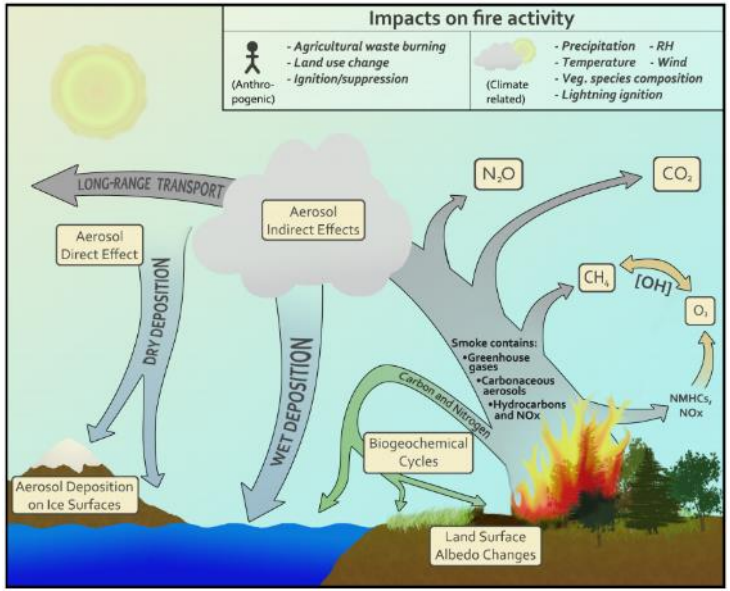
Working towards a coupled interactive fire-atmospheric-composition model



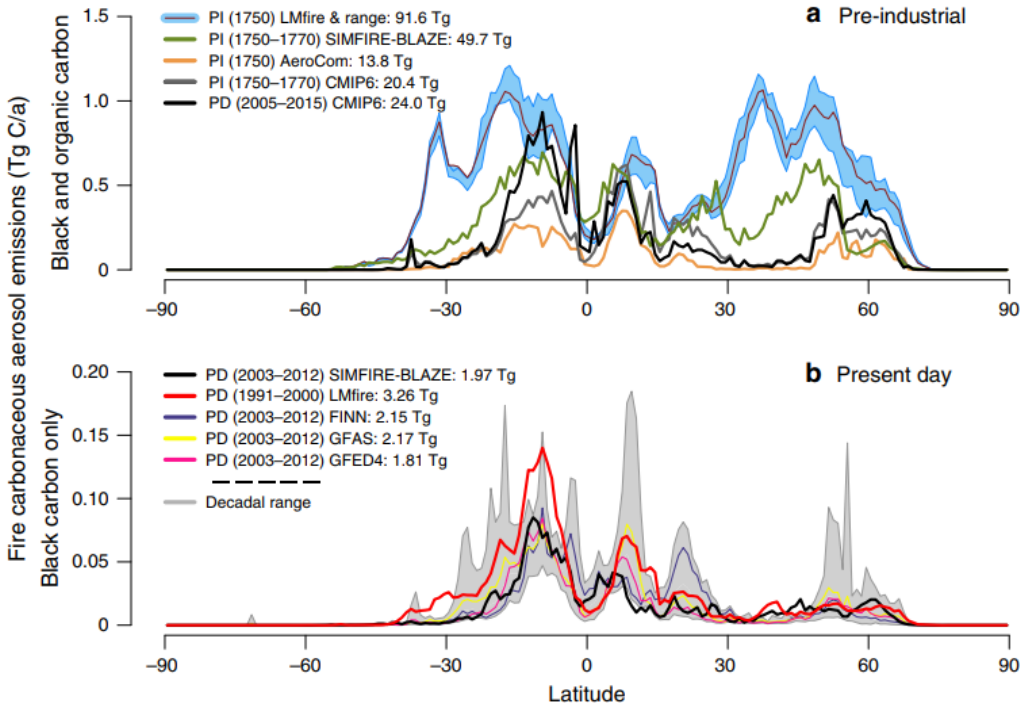
J.C Teixeira, G. Folberth,
F. O'Connor, A. Voulgarakis, N. Unger

Atmospheric Science Conference
02/07/2019

Fire in the Earth System



Impacts of fire on the atmosphere, land surface, ice surfaces and the ocean (Ward et al., 2012)



Fire carbonaceous aerosol emissions (Hamilton et al. 2018)

Objectives

➔ **Development and application** of a coupled vegetation-fire-composition-climate Earth system model

➔ **Quantification of the impacts** of fire variability on atmospheric composition-climate

- Radiative forcing of climate
- Fire-composition-climate feedback

INFERNO

Fire weather conditions
Precipitation
Temperature
Relative Humidity

Fuel Density

Soil Moisture

Goff-Gratch saturation vapour pressure

Flammability

Ignition

Ignition Mode
- Constant
- Lightning
- Population and lightning

Burnt Area

Emissions

- ~~C~~
- CO
- ~~CO_2~~
- ~~CH_4~~
- NO_x
- SO_2
- BC
- OC

S. Mangeon et al. (2016): INFERNO - a fire and emissions scheme

Model Setup

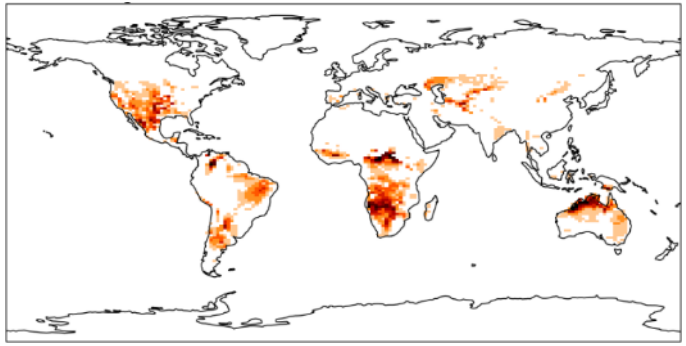
	Control	Experiment
Model setup basis	UKESM1-AMIP	
INFERNO	Diagnostic	Interactive
Period	1980-2010	
ignitions	Prescribed lightning (2010) Population density (2010)	
Biomass emissions	UKESM1 CMIP6	INFERNO (CO, NO_x, SO_2, BC, OC)

Observations dataset – GFED 4.1s burned area (including small fires) and emissions of burnt Carbon – from 1997 to 2010

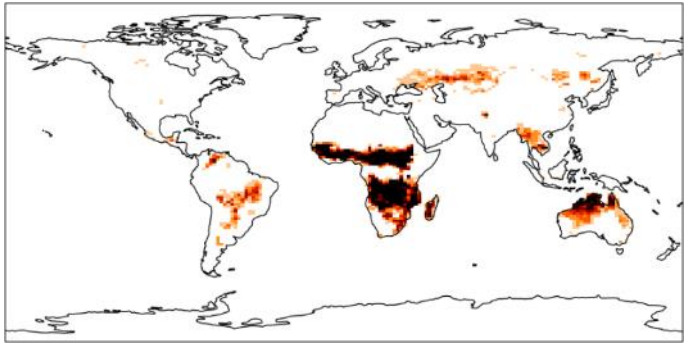
Giglio, L. et al. (2013), 'Analysis of daily, monthly, and annual burned area using the fourth-generation global fire emissions database (gfed4)'

Mean Annual Burnt Area Fraction *(% year^{-1})*

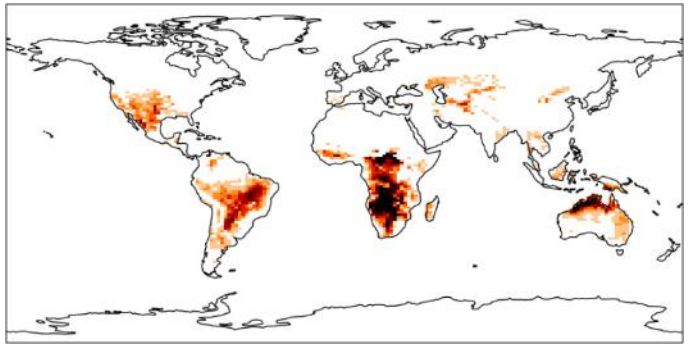
UKESM1-AMIP INFERNO Diagnostic (1980-2010)



GFED 4.1s (1997-2010)

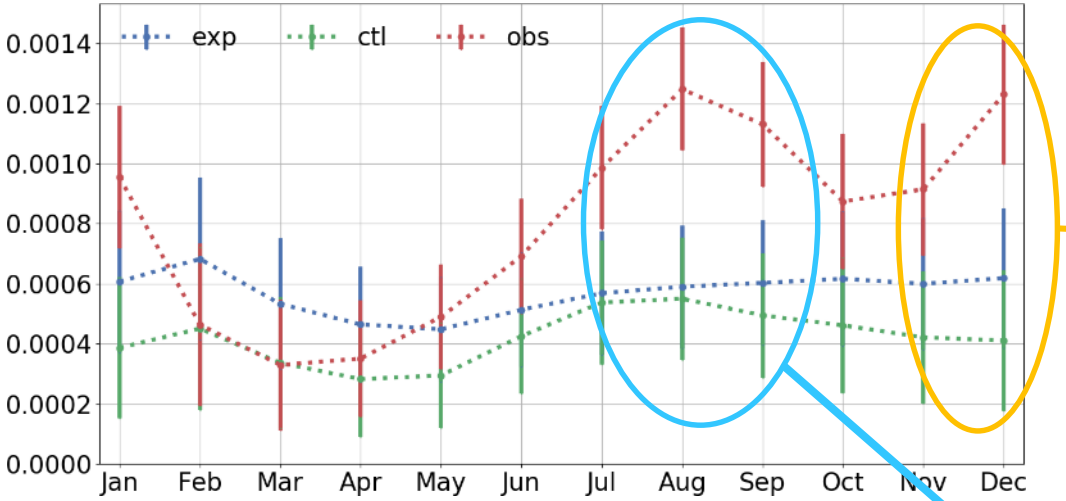


UKESM1-AMIP INFERNO Interactive (1980-2010)

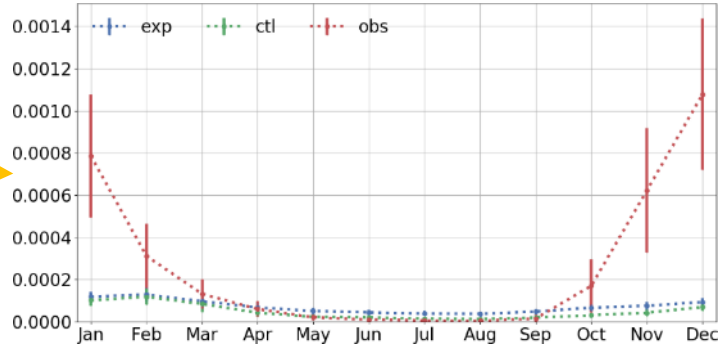


- Agreement with observations on spatial patterns
- Overestimation over N. America
- Underestimation over Africa

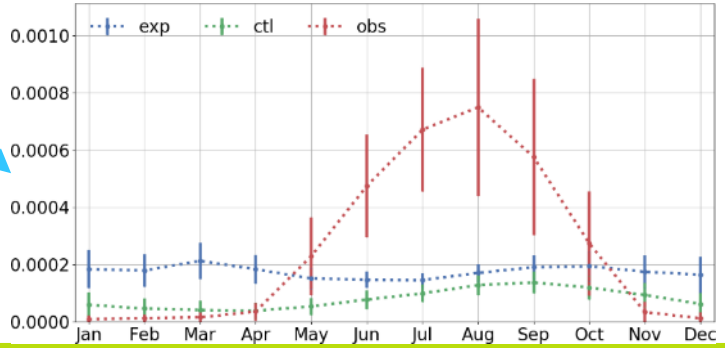
Burnt Area fraction Monthly Climatology *(fraction month^{-1})*



Northern Hemisphere Africa



Southern Hemisphere Africa



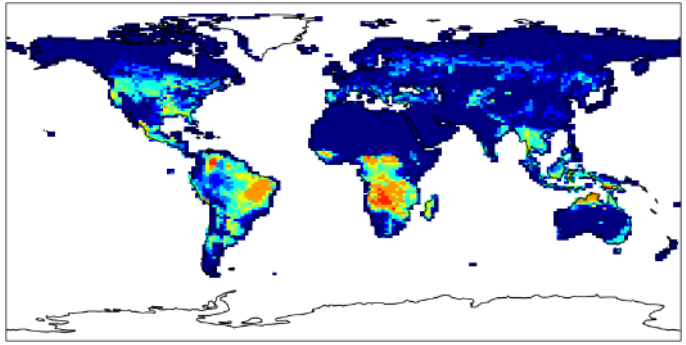
UKESM1-AMIP INFERNO Interactive

UKESM1-AMIP INFERNO Diagnostic

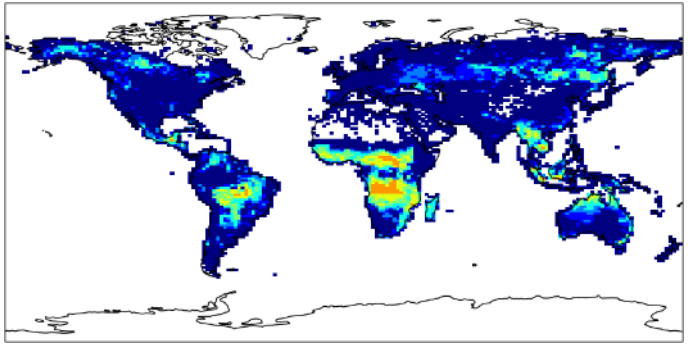
GFED 4.1s

Mean Annual Carbon emission *(kg m $^{-2}$ year $^{-1}$)*

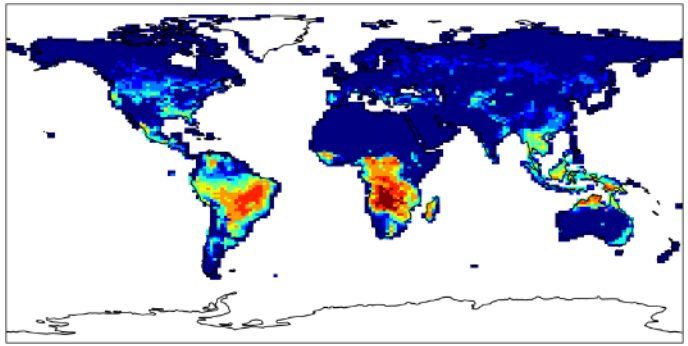
UKESM1-AMIP INFERNO Diagnostic (1980-2010)

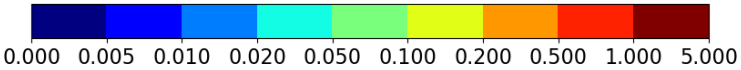


GFED 4.1s (1997-2010)



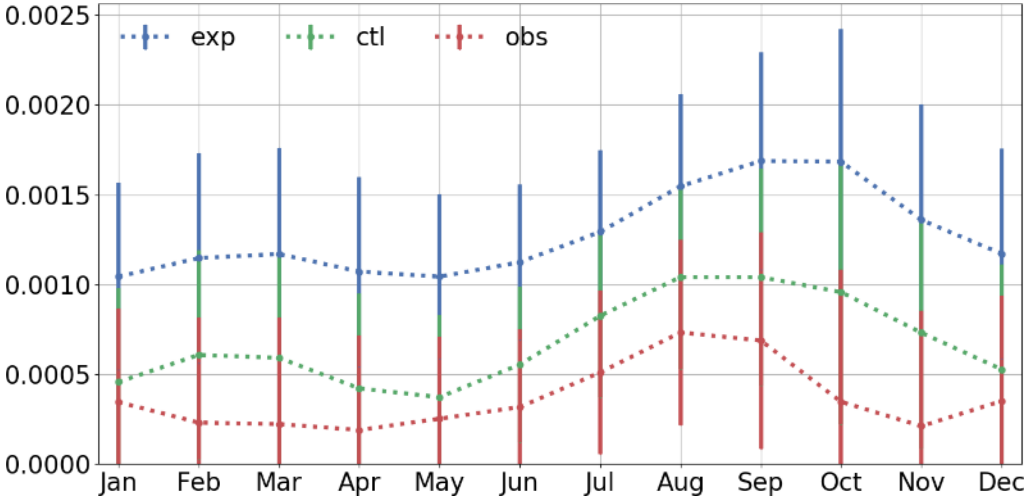
UKESM1-AMIP INFERNO Interactive (1980-2010)



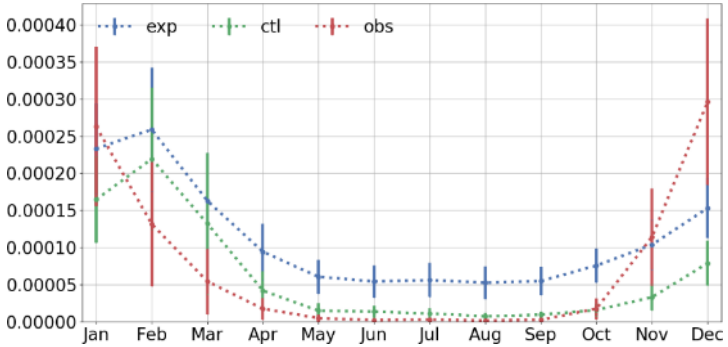


- Agreement with observations on spatial patterns
- Overestimation over N. America, S. America, Africa and Maritime Continent

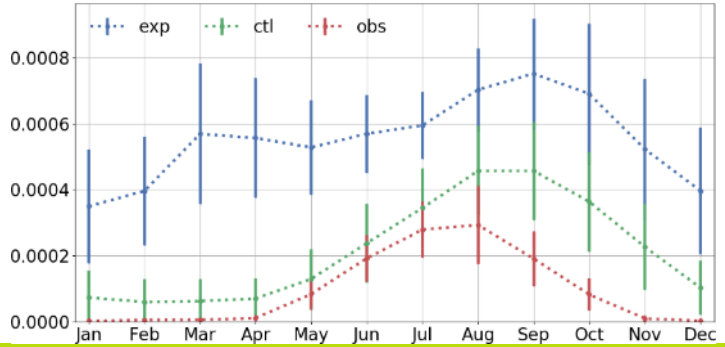
Emitted Carbon Monthly Climatology *(kg m $^{-2}$ year $^{-1}$)*



Northern Hemisphere Africa



Southern Hemisphere Africa

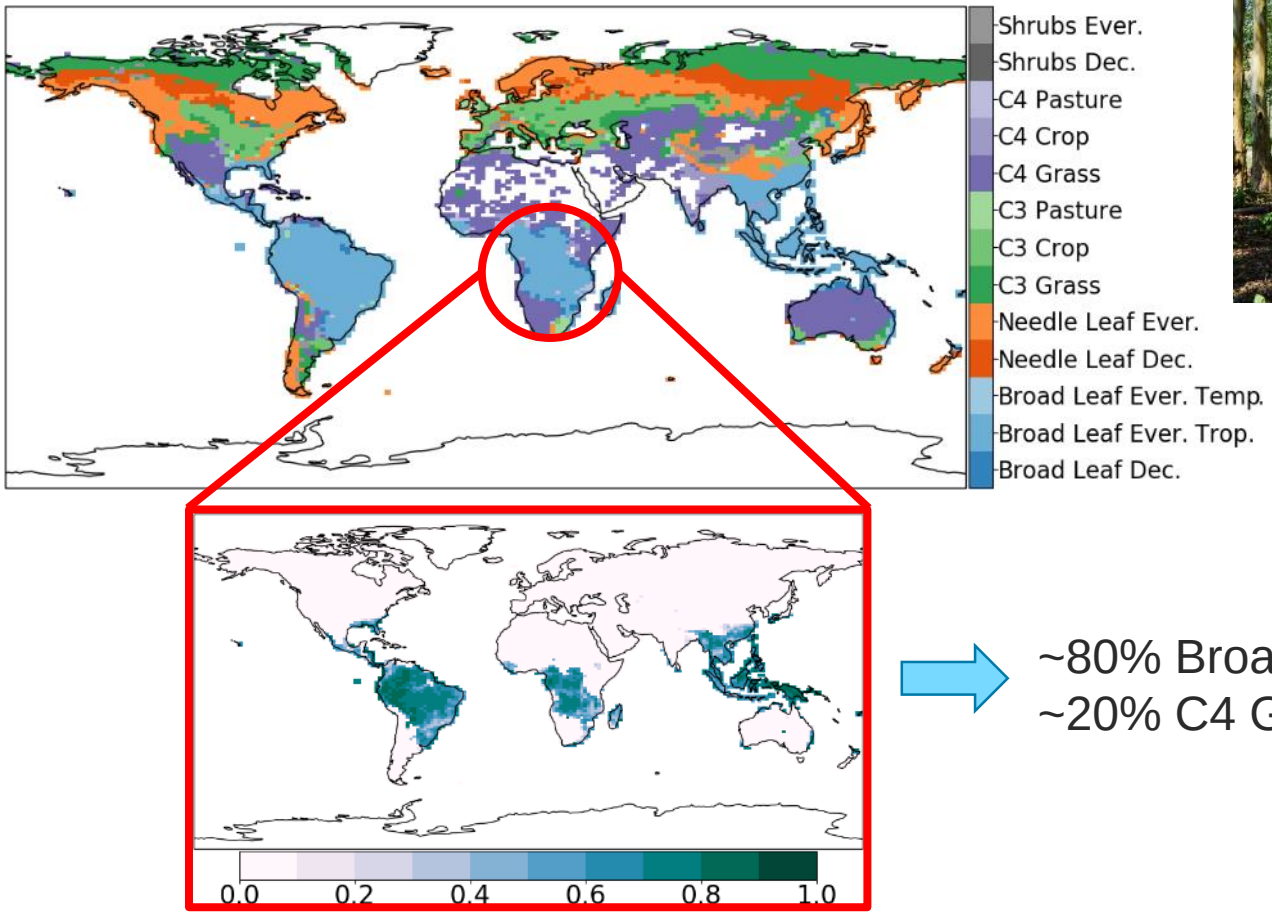


UKESM1-AMIP INFERNO Interactive

UKESM1-AMIP INFERNO Diagnostic

GFED 4.1s

What's wrong?



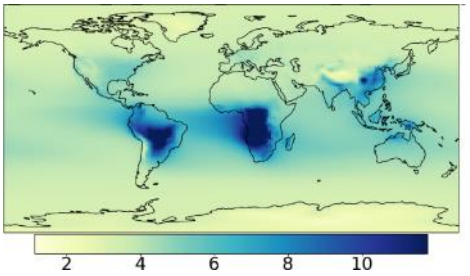
~80% Broad Leaf Evergreen Tropical
~20% C4 Grass

Atmospheric composition - Troposphere column

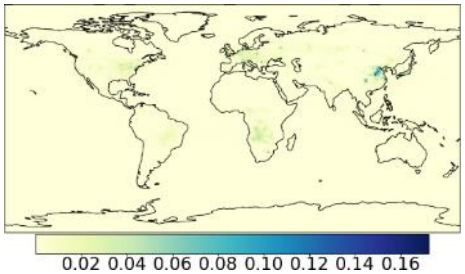
Mass mixing ratio

UKESM1-AMIP INFERNO Interactive (1980-2010)

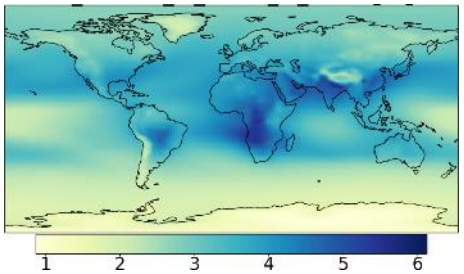
CO *(mg kg^{-1})*



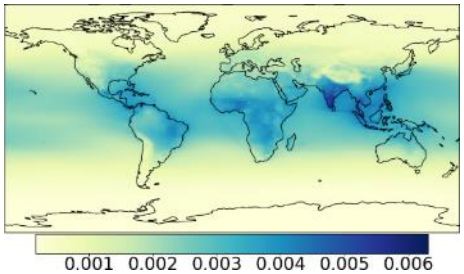
NO_x *(mg kg^{-1})*



O3 *(µg kg^{-1})*

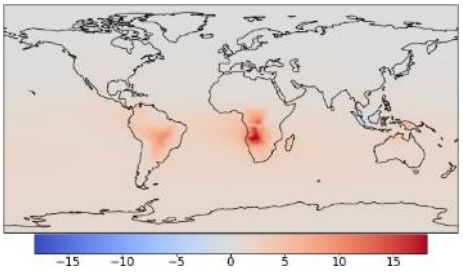


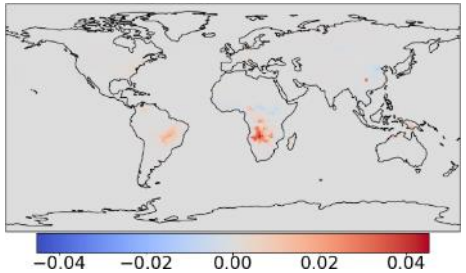
OH *(mg kg^{-1})*

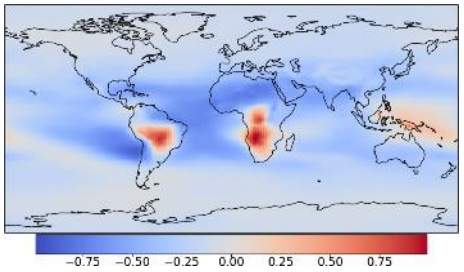


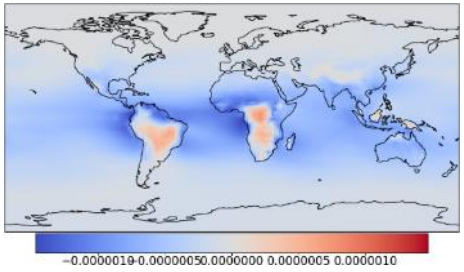
Difference

(interactive – diagnostic INFERNO)









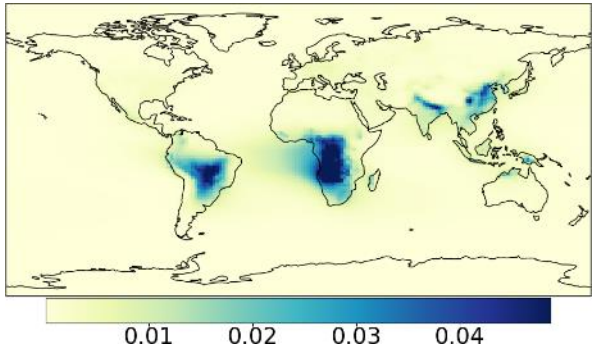
Atmospheric composition - Total column

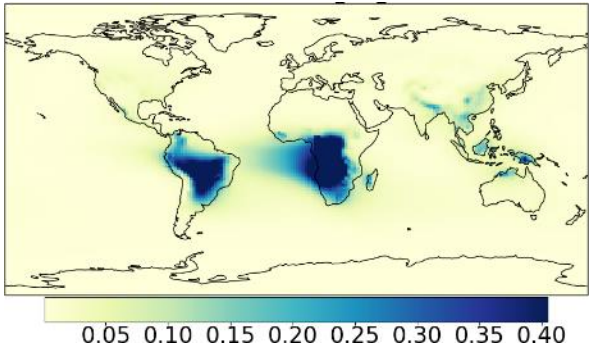
BC *(mg kg^{-1})*

OC *(mg kg^{-1})*

Mass mixing ratio

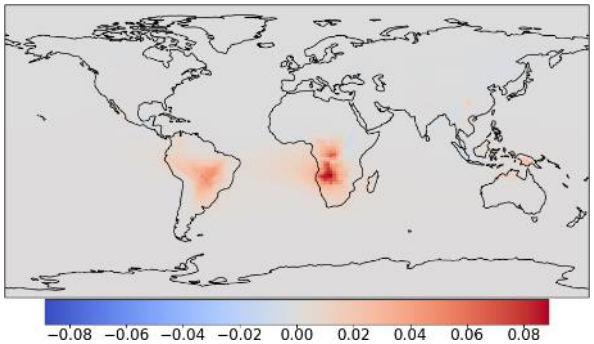
UKESM1-AMIP INFERNO Interactive (1980-2010)

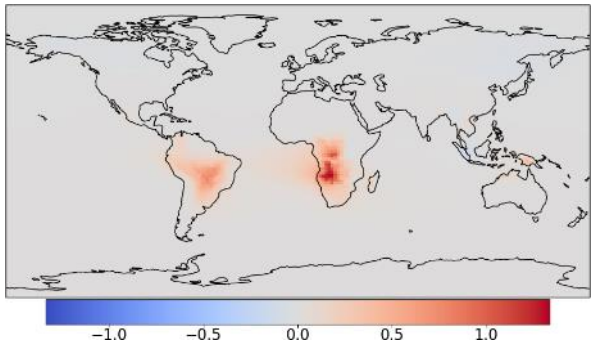




Difference

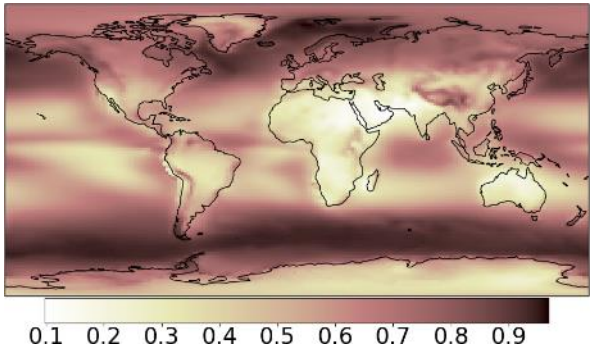
(interactive – diagnostic INFERNO)

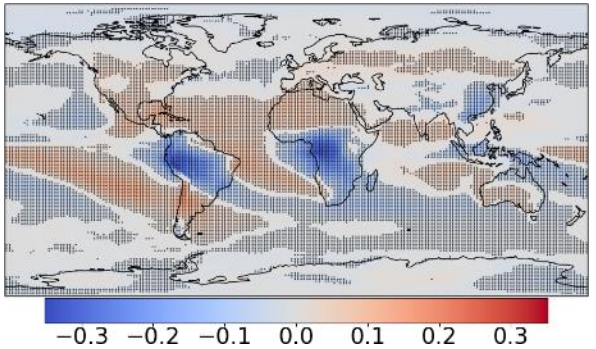




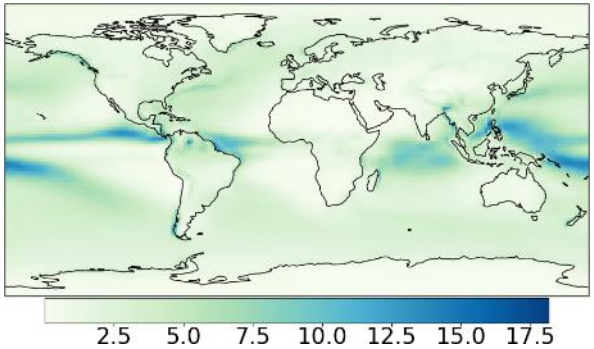
Impact on clouds and precipitation

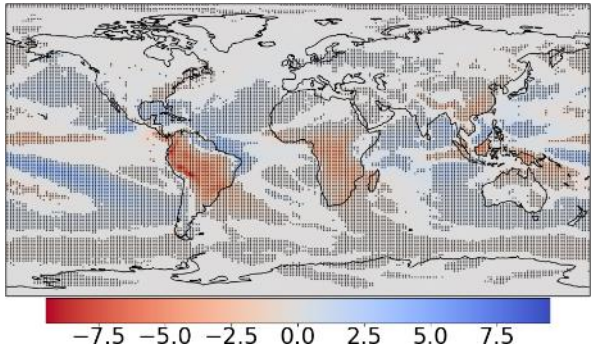
Total Cloud





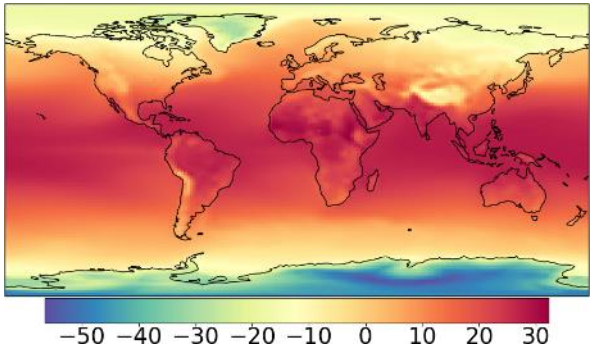
Precipitation

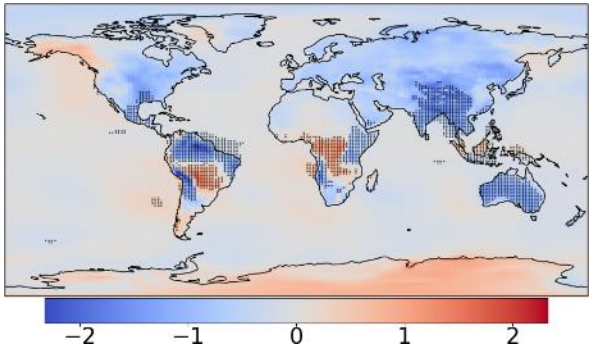




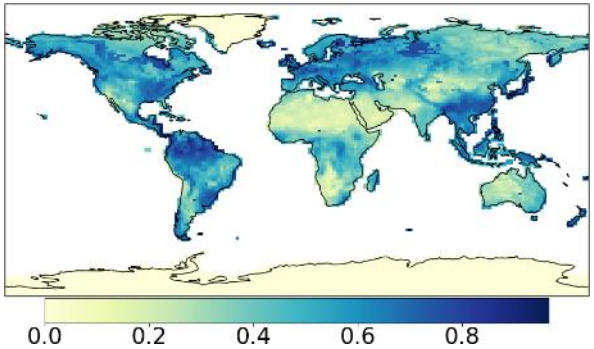
Impact on temperature and soil moisture

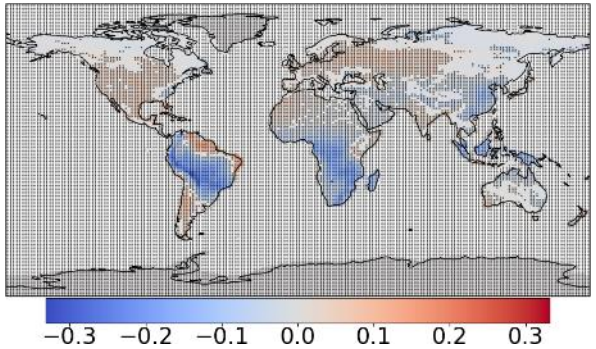
1.5 m Temperature





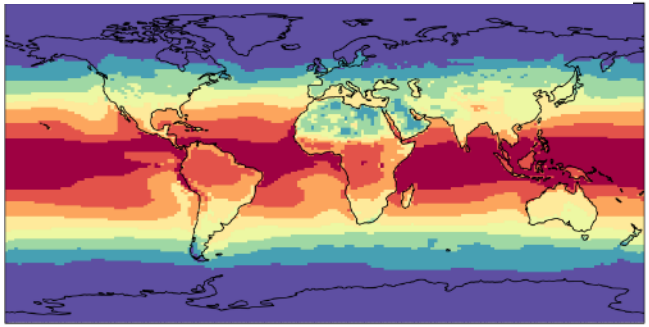
Unfrozen soil moisture



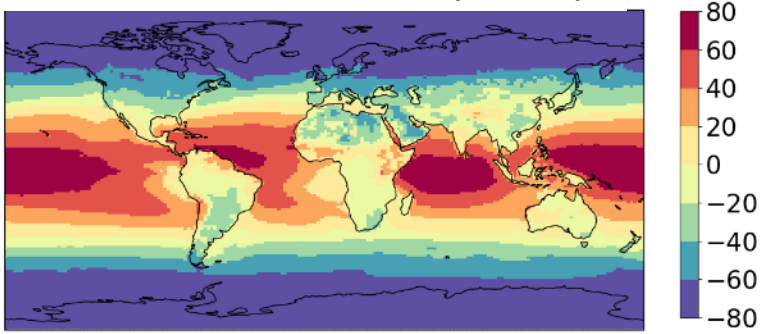


Radiation Balance at TOA *(W m^{-2})*

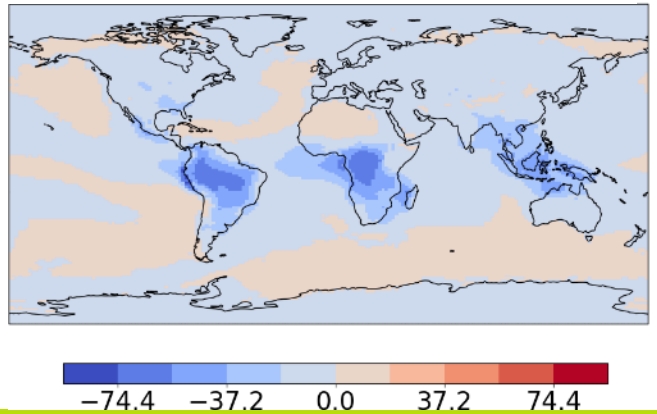
UKESM1-AMIP INFERNO Diagnostic (1980-2010)



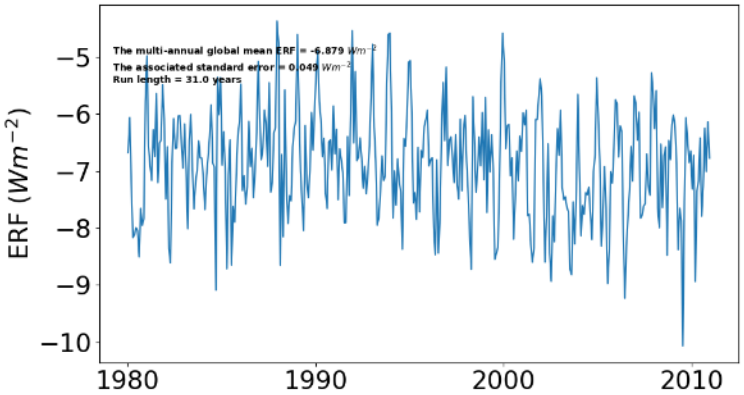
UKESM1-AMIP INFERNO Interactive (1980-2010)



ERF – due to differences in the two experiments



ERF per year



Summary

- Implementation of the online coupling to the atmospheric model
  - Allowing for a fire-atmosphere-composition two way interaction
  - Fires change Earth's radiative balance which feedback to the atmospheric controls of fires
- Biases in underlying vegetation are the main reason for biases in fire emissions
  - Model gives the wrong for the right reason
  - Implications for atmospheric and climate feeding back to fire

Next Steps

- Understand how to improve/constraint the land surface properties
- Evaluation of the impact fires in composition
- Response of fire and compositions in fire
- Climate-fire feedbacks in future climates

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