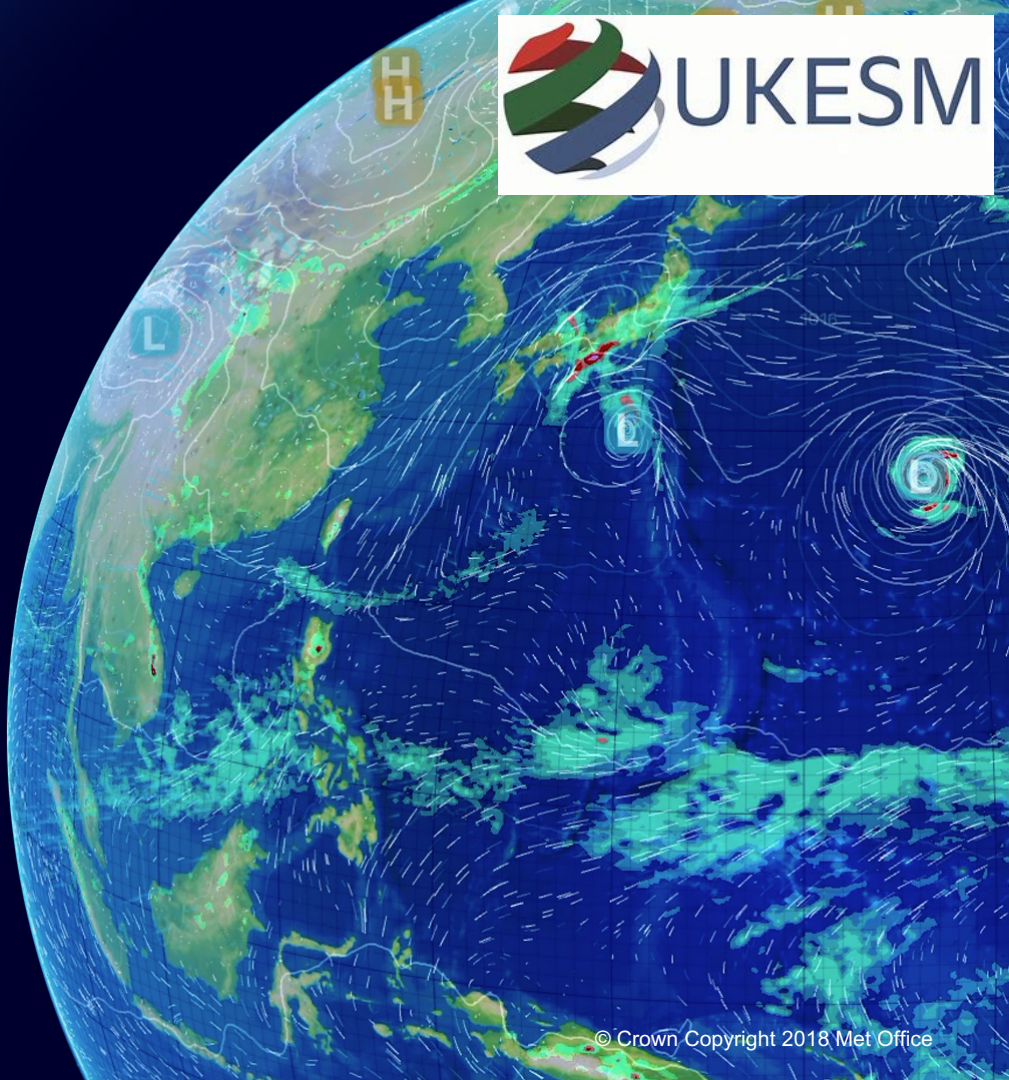


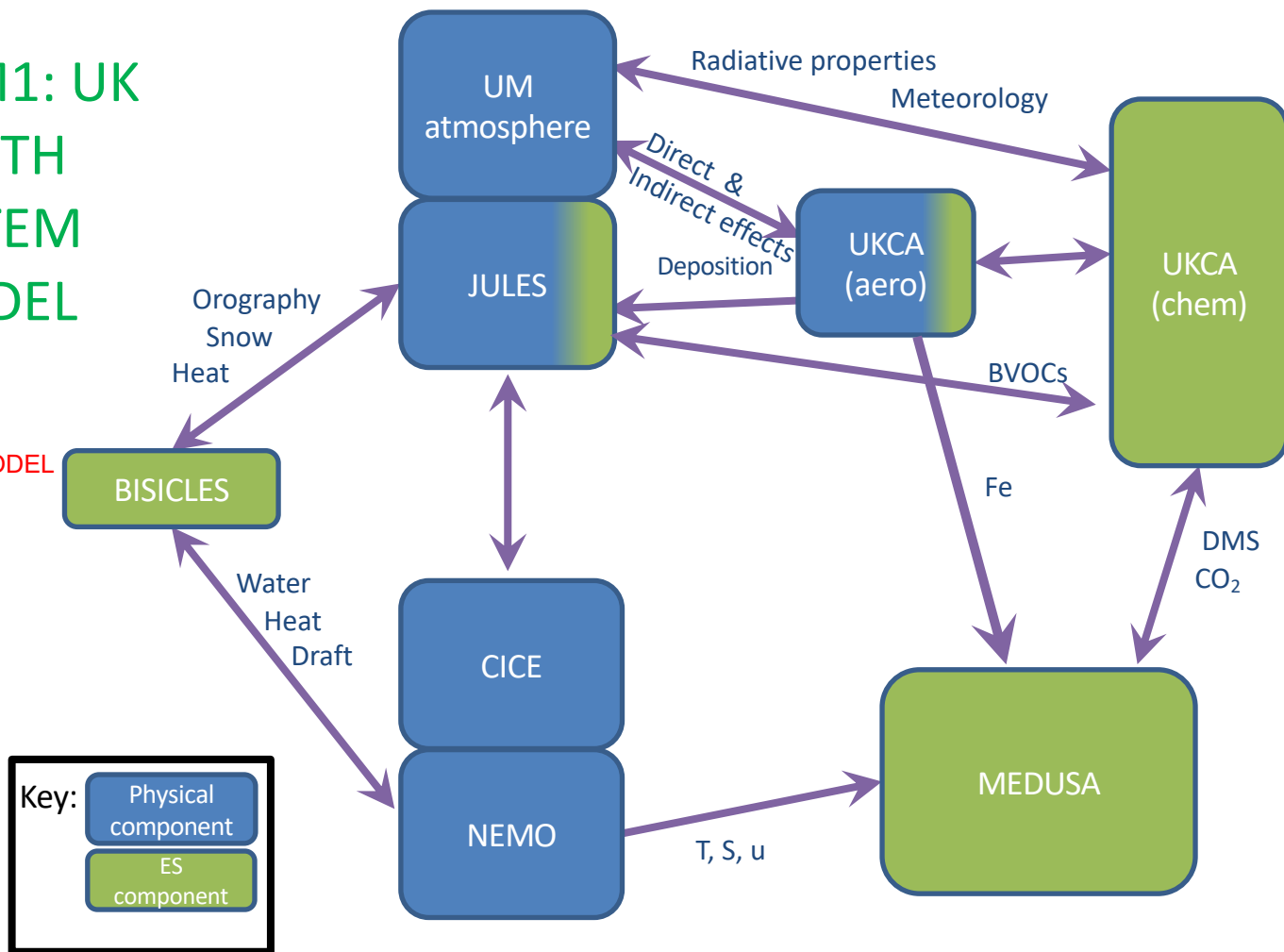
# UKESM1: Land Use scheme and initial results from CMIP6 LUMIP simulations

Eddy Robertson, Chris Jones,  
Spencer Liddicoat, Andy Wiltshire



# UKESM1: UK EARTH SYSTEM MODEL

LAND ICE SHEET MODEL  
NOT INCLUDED IN  
STANDARD UKESM1



# Land cover in UKESM1

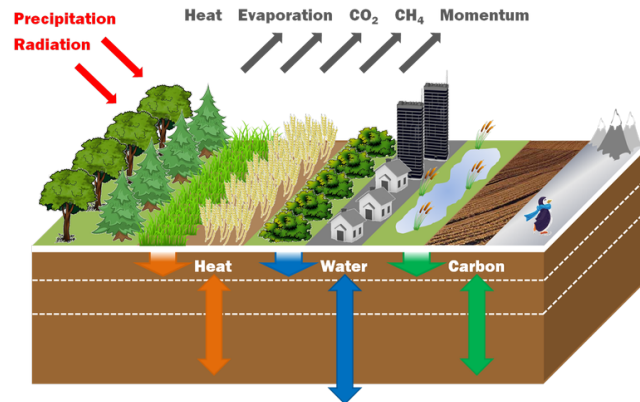
Gridboxes contain 4 distinct regions:

- Non-vegetated (urban, lakes)
- Vegetated
  - natural (5 tree / 2 shrub / C3, C4 grass PFTs)
  - crop (C3, C4 grass PFTs)
  - pasture (C3, C4 grass PFTs)

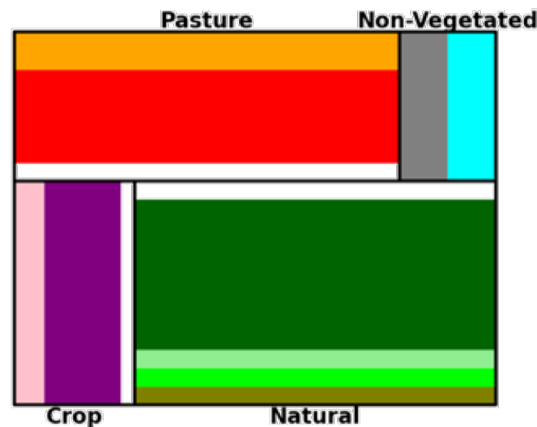
Competition between PFTs occurs separately in each region via TRIFFID DVGM

- relative abundance of PFTs in each region is therefore consistent with the climate.

Land portions of UKESM1 gridboxes are either 100% ice, or are made up of three vegetated, and one non-vegetated regions



Schematic of JULES land surface model within UKESM1



# Crop and Pasture in UKESM1

The **fractions of the gridbox** in which Crop + Pasture can grow are prescribed

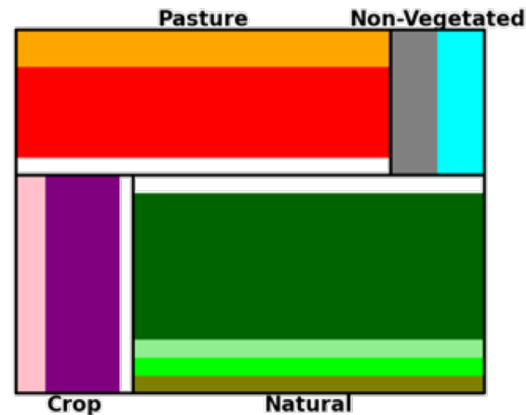
- As crop + pasture areas grow, natural plants are cleared away
  - Aboveground biomass put into **wood product pools**
  - Wood product pools **decay releasing CO<sub>2</sub>**
- Changes to crop / pasture area are **net transitions** not gross transitions

## Crops:

- 30% of crop litter is intercepted as a '**harvest flux**'
- Prevents unrealistic accumulation of soil carbon in productive croplands
- Provides **metric of crop productivity**
- Crop PFTs are not nitrogen limited: perfect **fertilizer application**
  - Fertilizer flux exactly meets crop nitrogen demand – no accumulation in soil

## Pasture:

- Not grazed
- Not fertilized or harvested



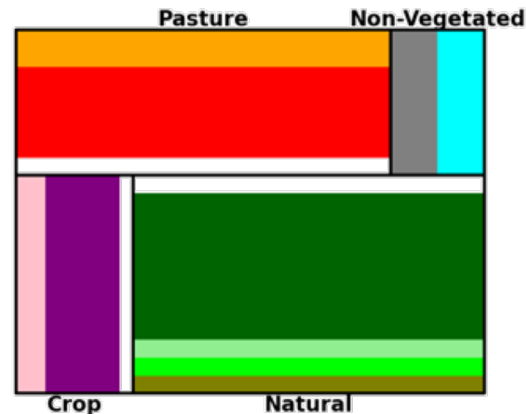
Crop and Pasture regions change over time  
Non-vegetated region is fixed  
Natural vegetation can grow in the remainder

Description paper of  
UKESM1 land use  
scheme is being written  
by Eddy Robertson.

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Land use + land use change CO<sub>2</sub> emissions in  
UKESM1 are the sum of the **decay of the  
wood product pools** plus the **crop harvest flux**

# Implementation of LUH2

Crop + pasture fraction ancillaries created from the following variables of LUH2:

**PASTURE** = **pastr**: managed pasture

Rangeland was not included in pasture fraction to avoid excessive deforestation.

**CROP** =  
+ **c3ann**: C3 annual crops  
+ **c3per**: C3 perennial crops  
+ **c4ann**: C4 annual crops  
+ **c4per**: C4 perennial crops  
+ **c3nfx**: C3 nitrogen-fixing crops

Re-gridded to UKESM1 grid in Python + Iris

# Met Office CMIP6: LUMIP experiments

Status as of 15<sup>th</sup> September 2019:

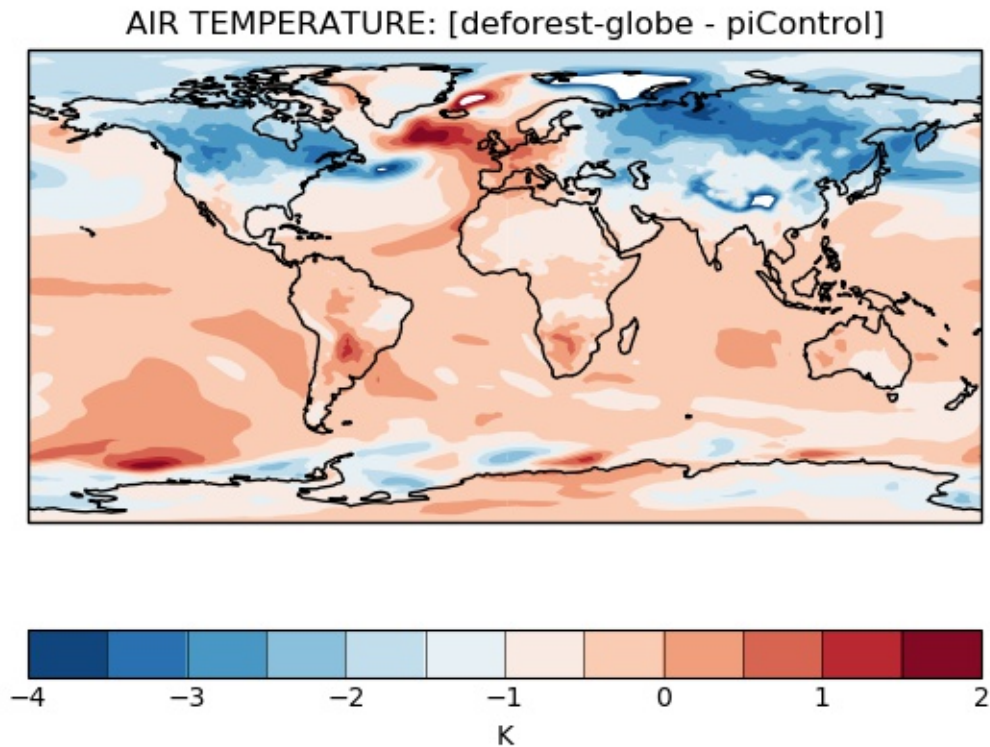
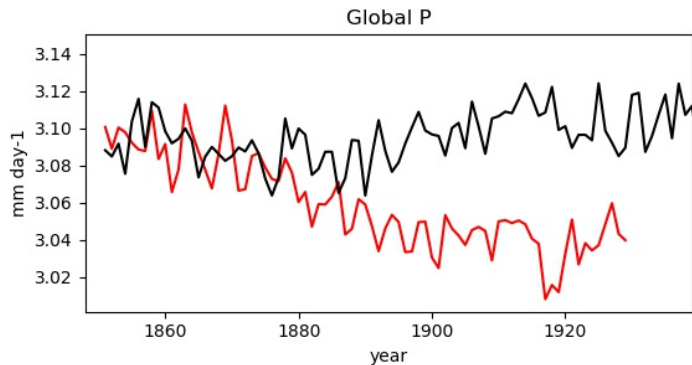
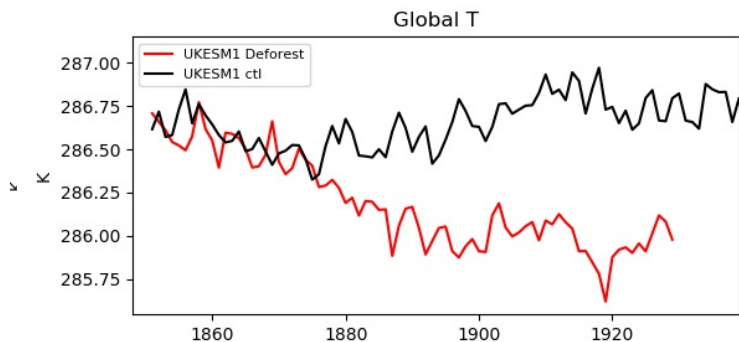
- deforest-globe (x1 completed, awaiting processing)
  - hist-noLu (x4: all completed, 3 submitted to ESGF)
  - 'mix and match' land use scenarios:
    - ssp370-ssp126-lu (x5: 1 submitted to ESGF, 4 still running)
    - ssp126-ssp370-lu (x5: 1 submitted to ESGF, 4 still running)
  - esm-ssp585-ssp126-lu (x1 completed, awaiting processing)
  - esm-ssp585-ssp126-lu-ext (x1 not started)
  - land only simulations (can only do a few and can't upload to ESGF but could share results informally if any interest)
- 
- Next slides show (mostly):
    - timeseries of global mean Tas and Pr
    - maps of differences in Tas and Pr between experiment and control (final decadal mean)



## PHASE 1

# deforest-globe vs piControl

- Global mean temperature: almost 1K cooler by end (though cooling trend at start of piControl)
- Regional differences up to 3-3.5K though no analysis of statistical significance yet

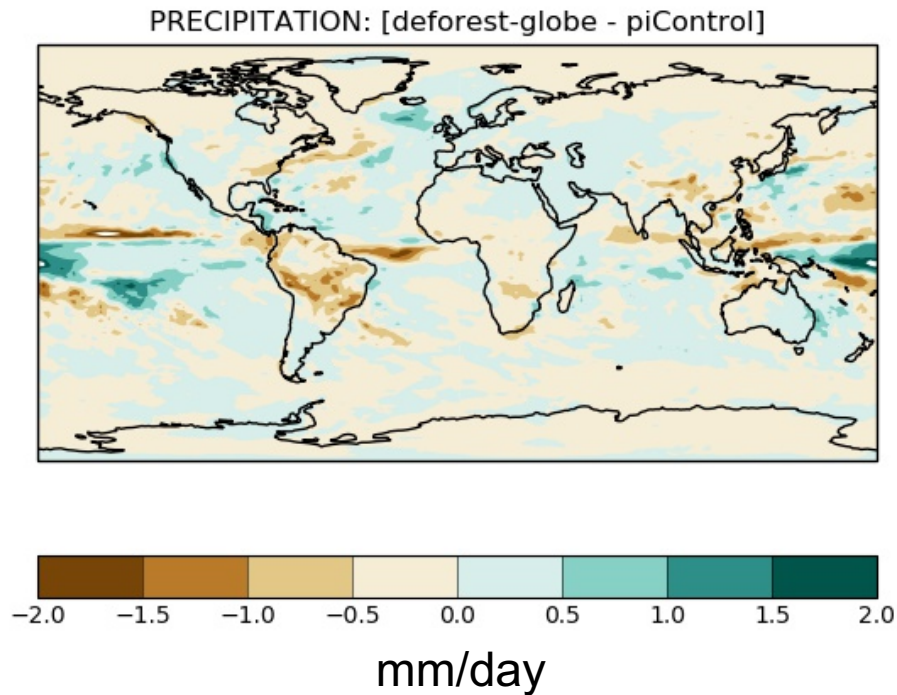
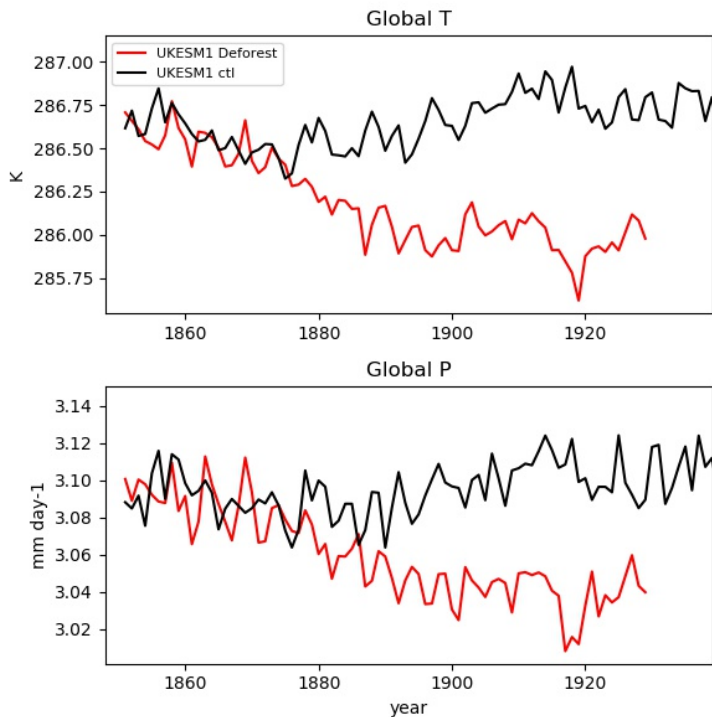




## PHASE 1

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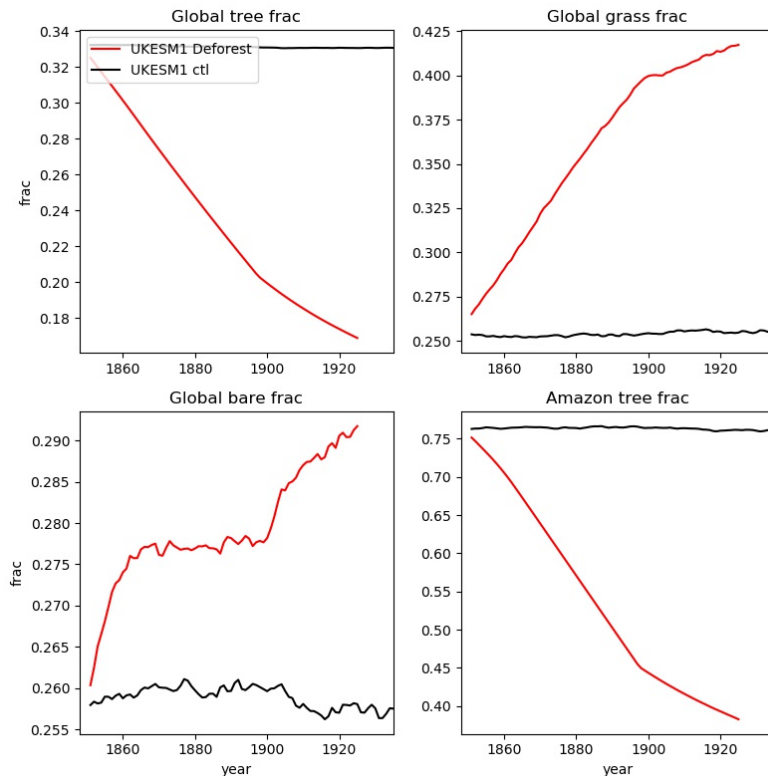
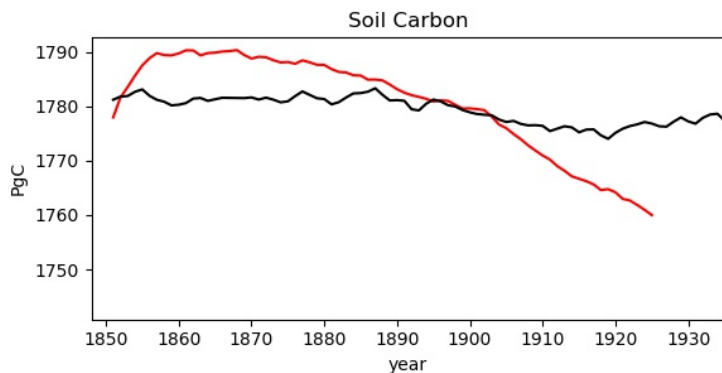
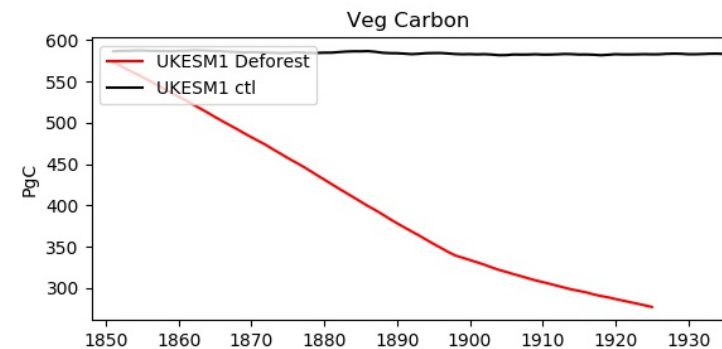
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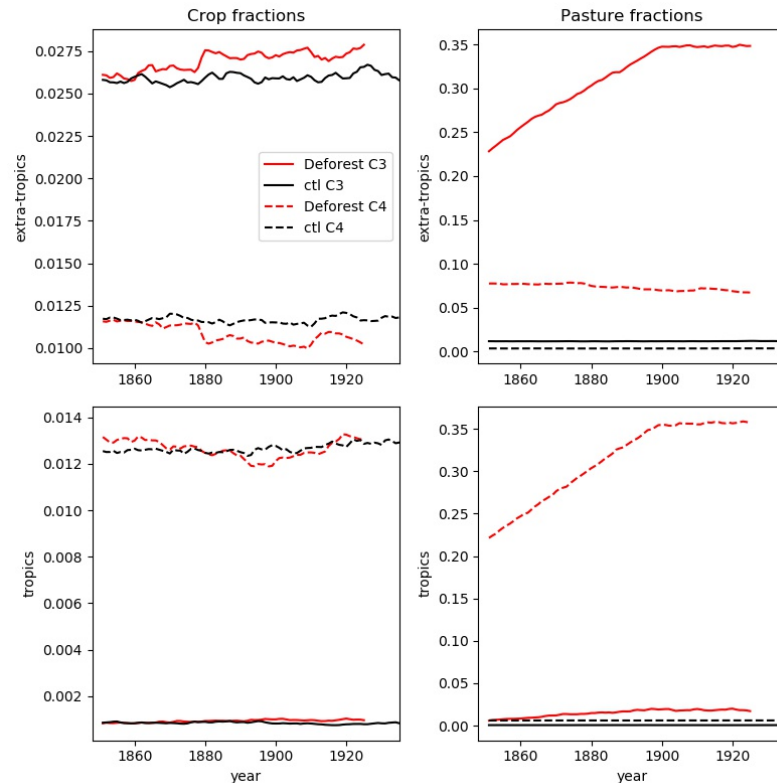
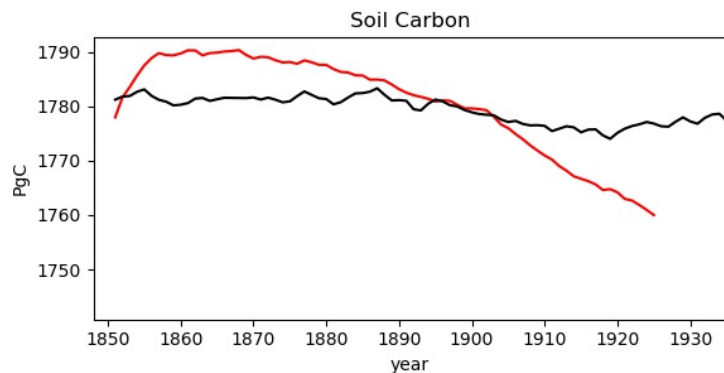
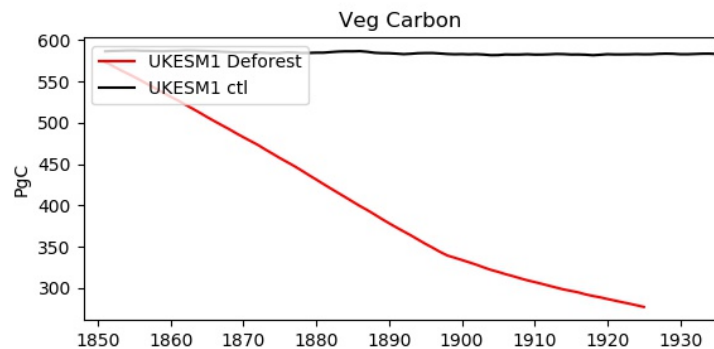
- Tree fraction continues to reduce after forced deforestation
  - Climate induced loss of trees



## PHASE 1

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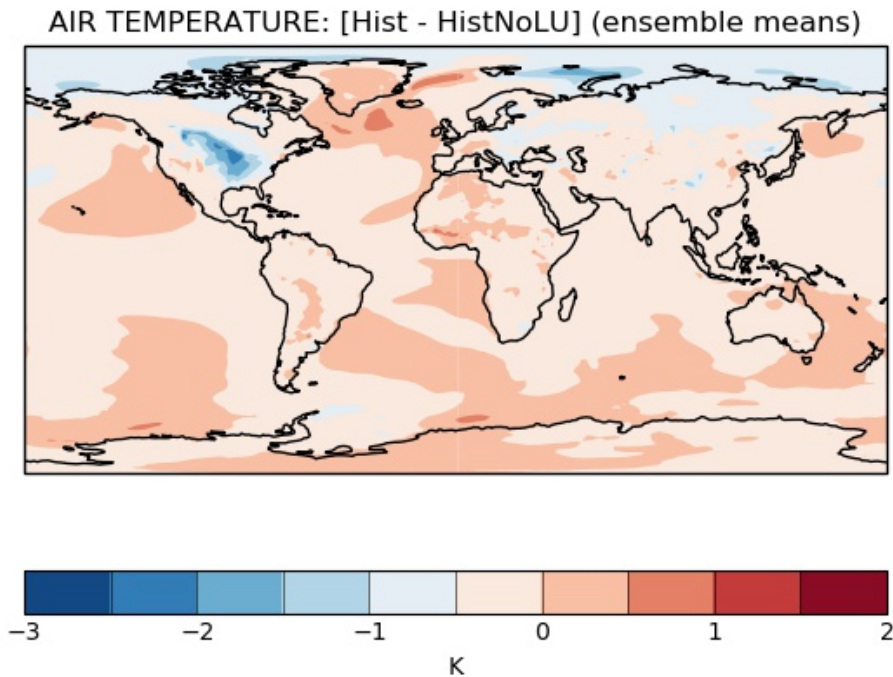
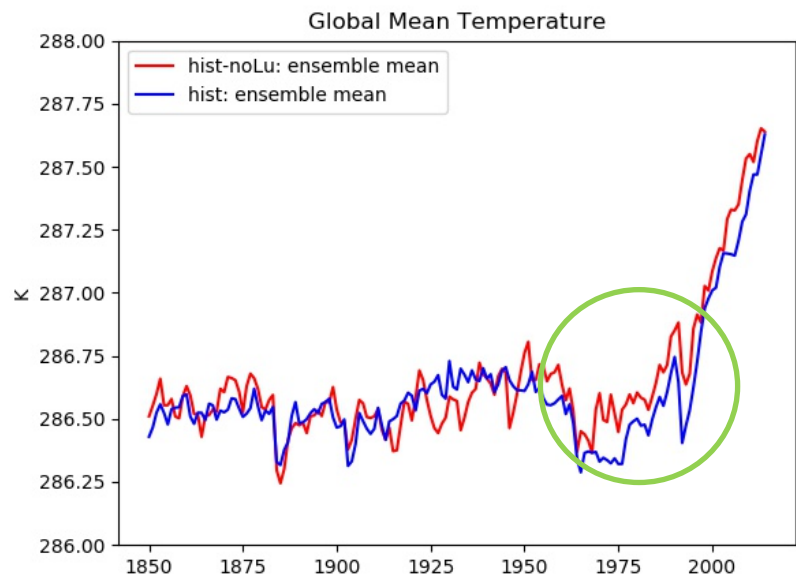
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## PHASE 2

# hist vs hist-noLu

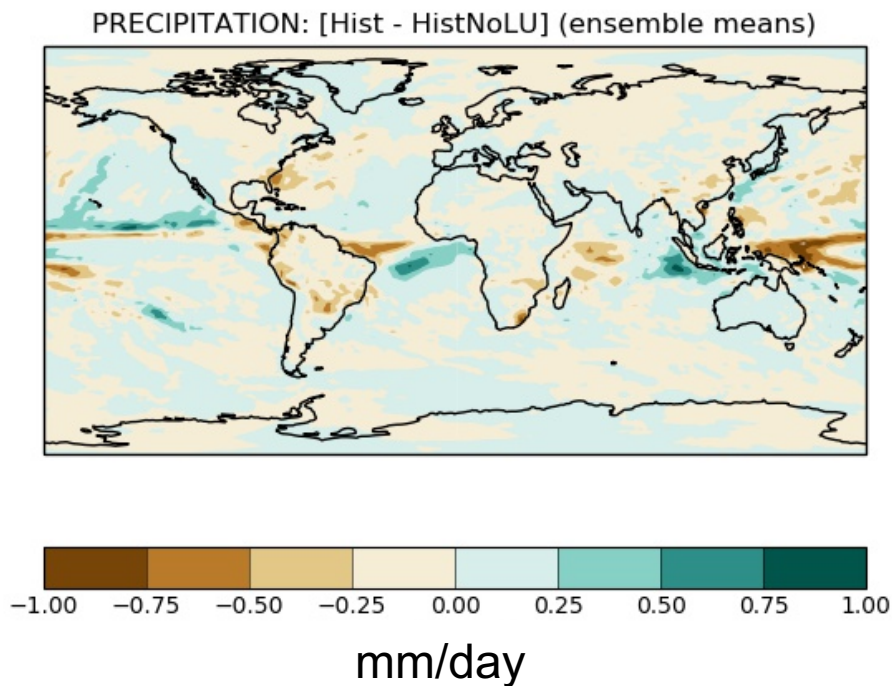
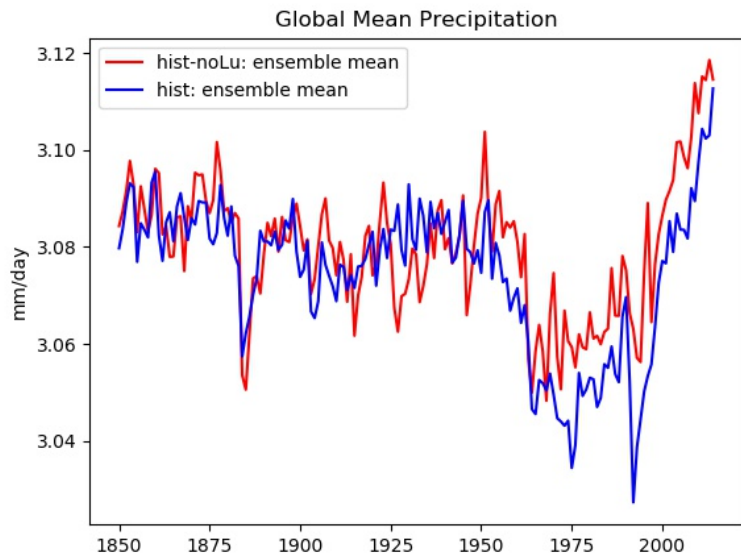
Evidence of land use contributing to cooling in 20<sup>th</sup> Century UKESM1 historical simulation.



## PHASE 2

# hist vs hist-noLu

...also a small impact on precipitation.

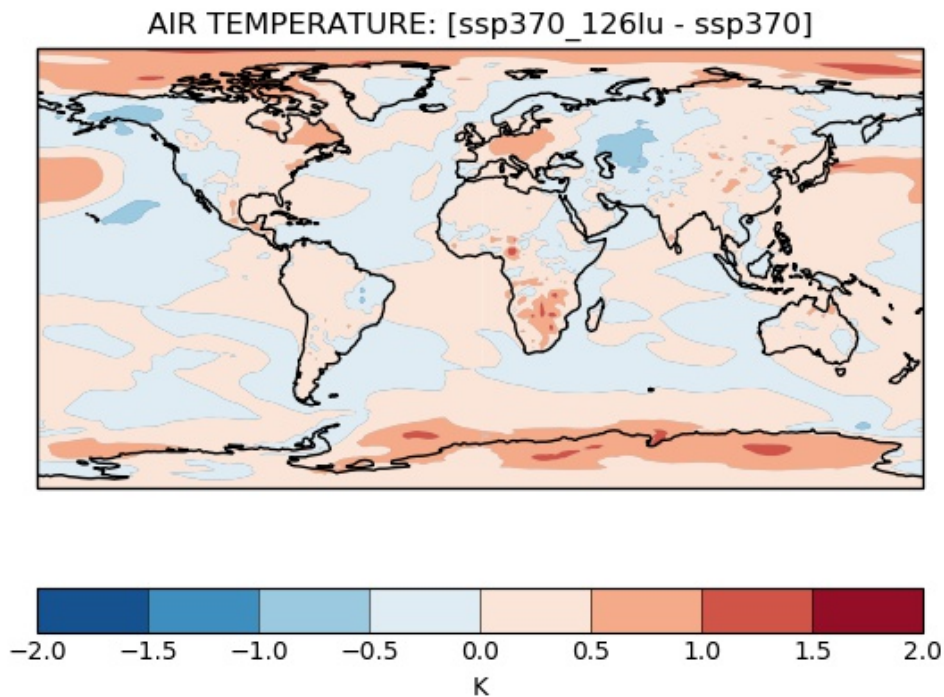
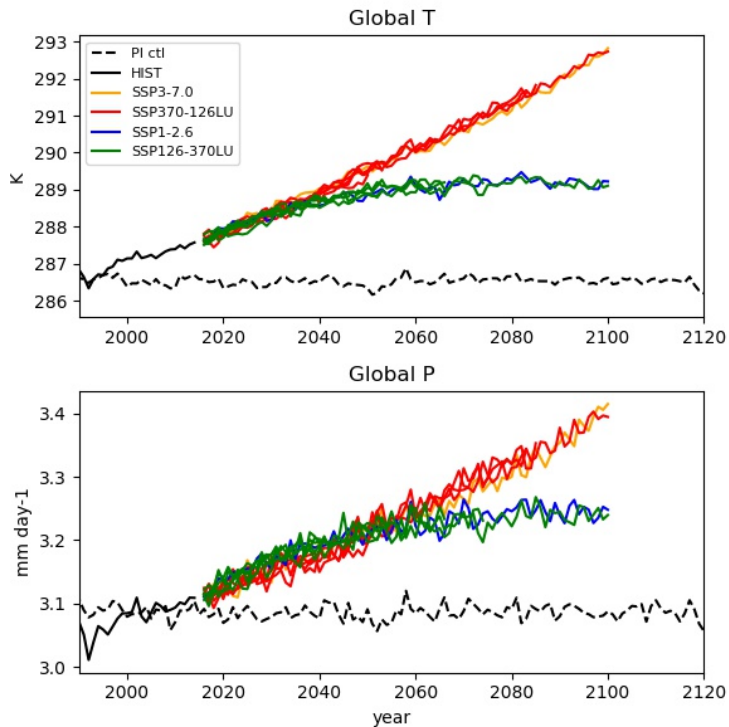


## PHASE 2

# ssp370-ssp126-lu vs ssp370

Red vs Yellow timeseries:

- little signal in global mean temperature or precipitation but ensemble running
- regional differences in final decadal mean temperature but statistical analysis not yet done



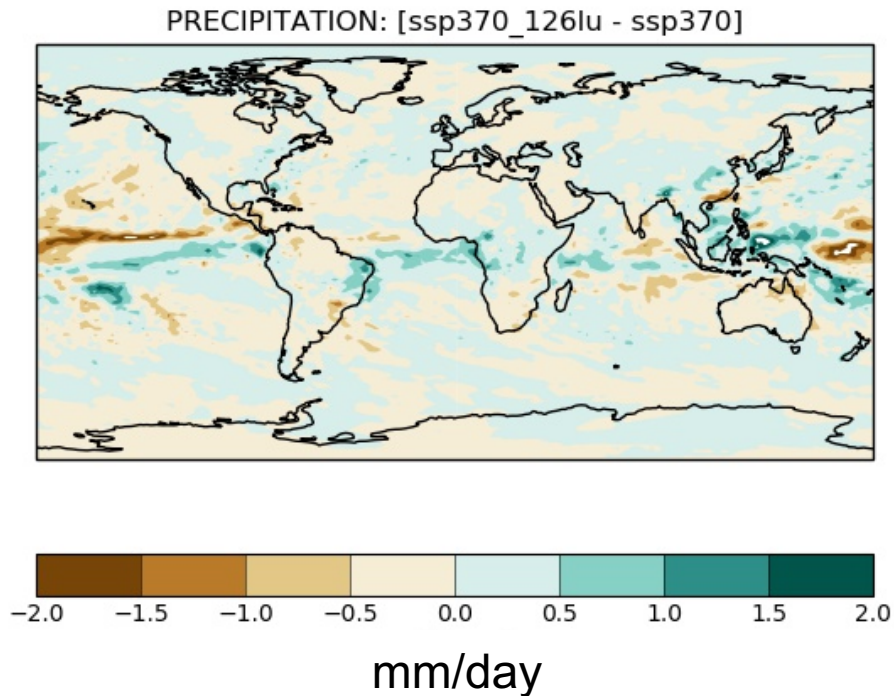
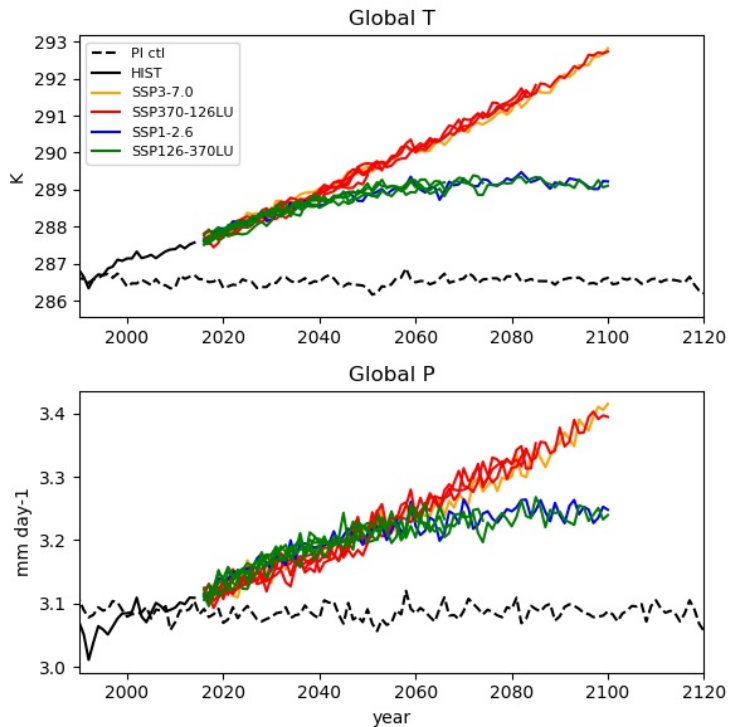


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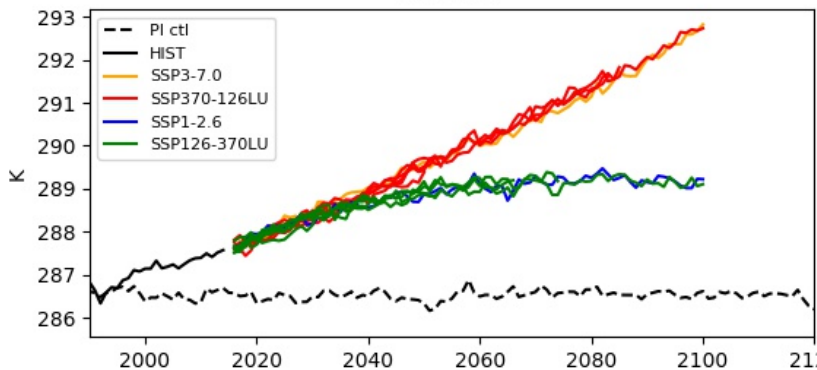
## PHASE 2

# ssp126-ssp370-lu vs ssp126

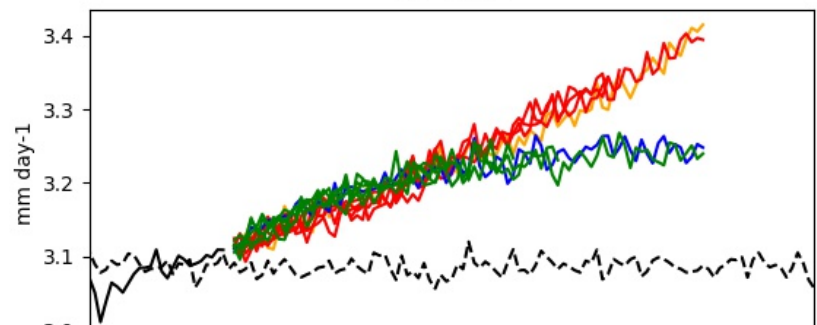
Blue vs Green timeseries:

- little signal in global mean temperature or precipitation but ensemble running
- stronger signal regionally than in red/yellow pair (statistical analysis not yet done)

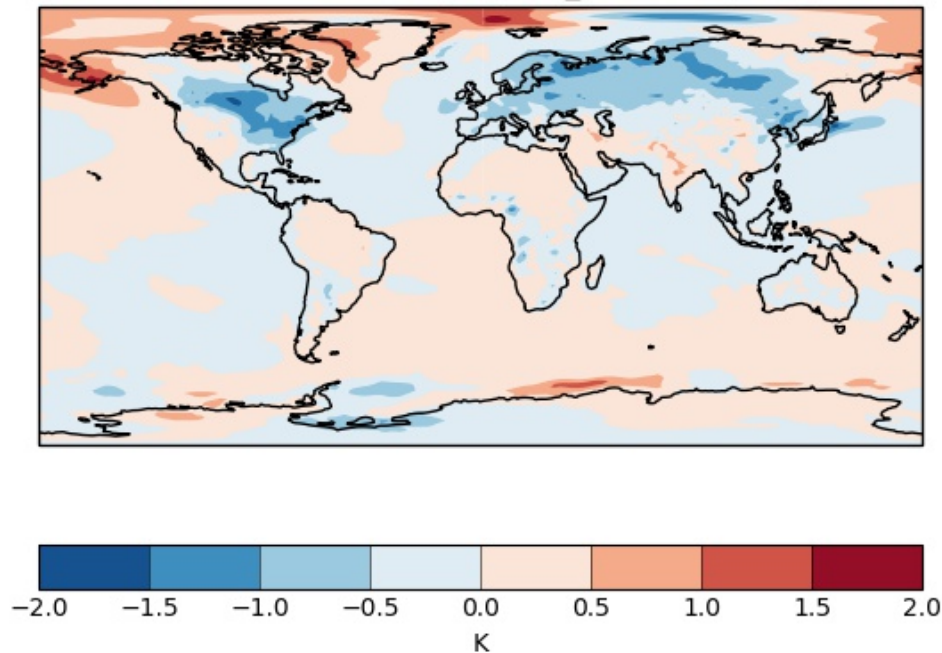
Global T



Global P



AIR TEMPERATURE: [ssp126\_370lu - ssp126]



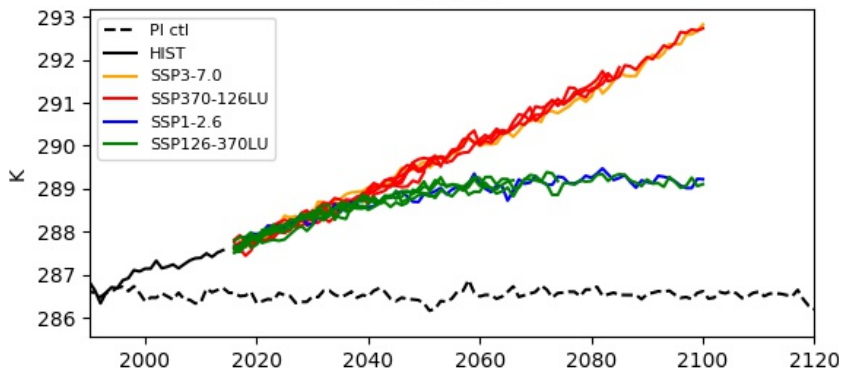
## PHASE 2

# ssp126-ssp370-lu vs ssp126

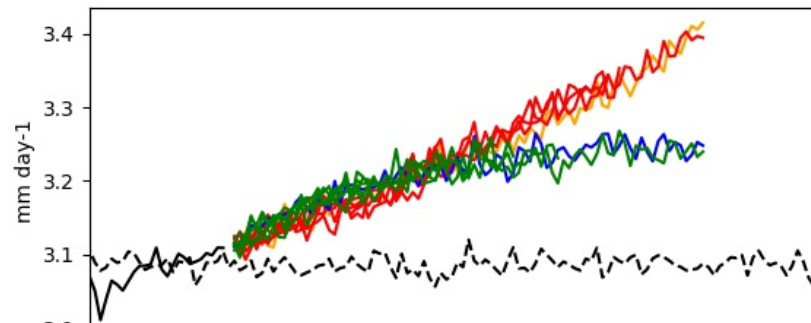
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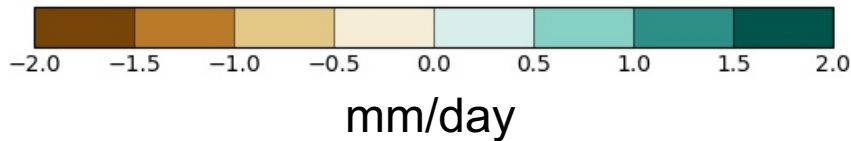
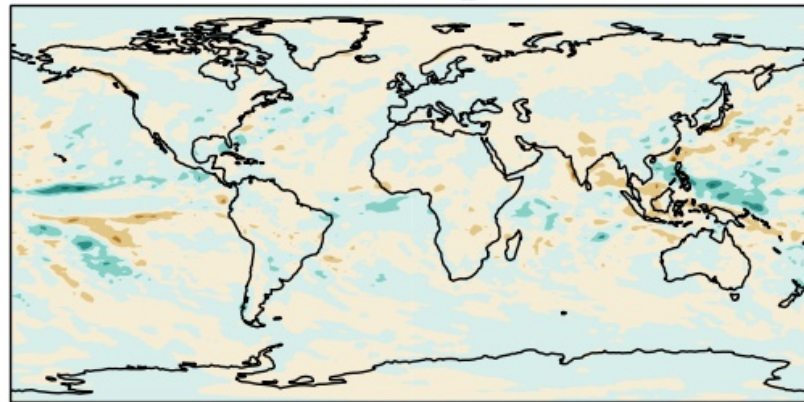
Global T



Global P



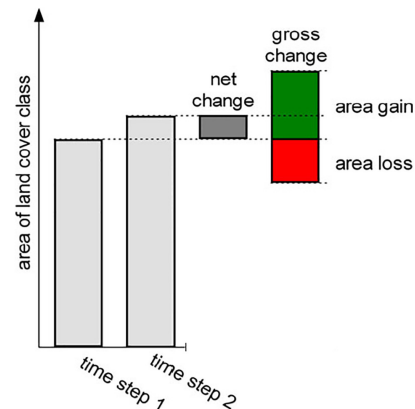
PRECIPITATION: [ssp126\_370lu - ssp126]



Thank you for your attention.

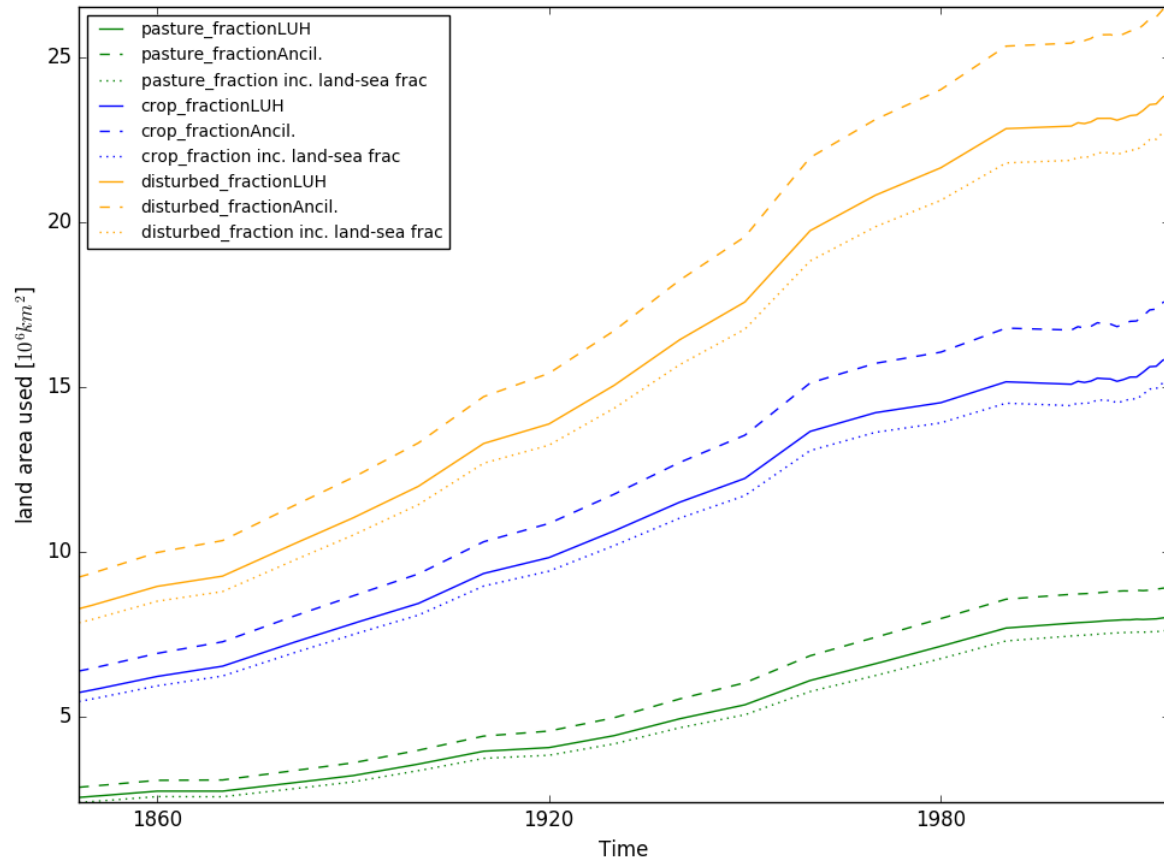
# Future of land-use in JULES / UKESM1

- Representation of “gross landuse transitions” may be added
- Other potential developments
  - Improvement of crop and pasture PFT parameter sets
    - ...to make them more realistic, distinct from natural grasses
  - Addition of other sub-grid regions:
    - forestry, biofuels
  - Improvement of management:
    - irrigation,
    - grazing of pasture,
    - wood harvest in forested regions
    - wildfire suppression in crop regions [fire not yet in UKESM1]



Net vs gross transitions  
from Fuchs *et al* Glob.  
Chang. Biol., 21 (1)  
(2015).

# LUH2 vs UKESM1 Crop and Pasture global area



LUH2 CROP  
UKESM1 CROP

LUH2 PASTURE  
UKESM1 PASTURE

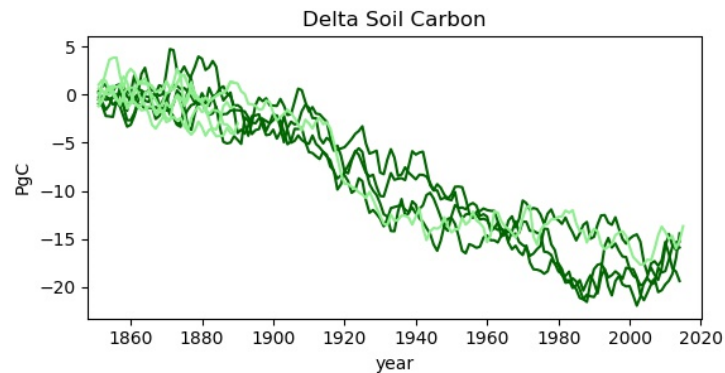
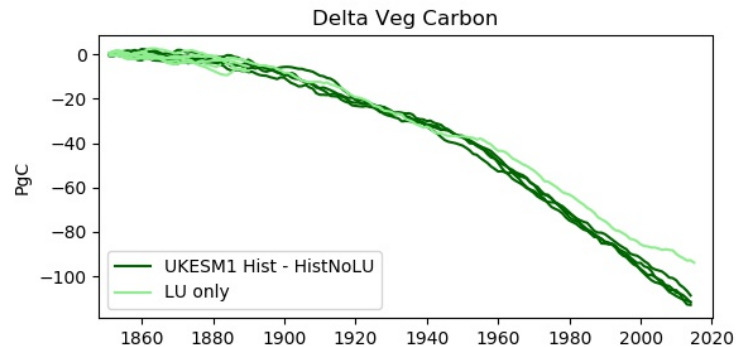
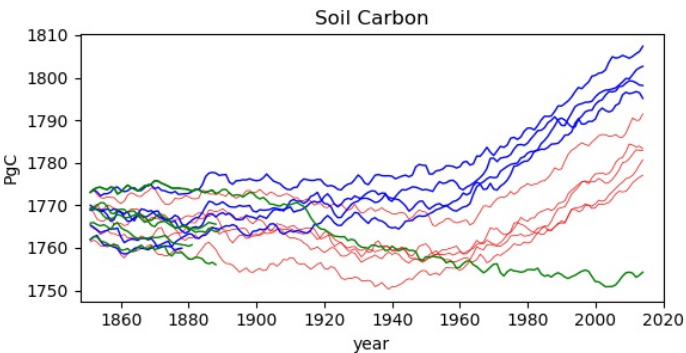
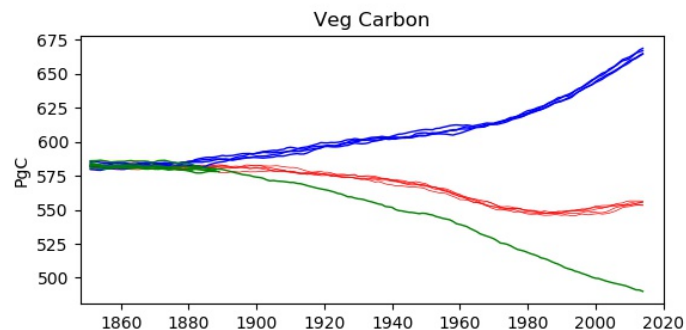
Not identical due to  
differences in total land  
area.

# hist vs hist-noLu

Hist-no-LandUse ensemble (blue)

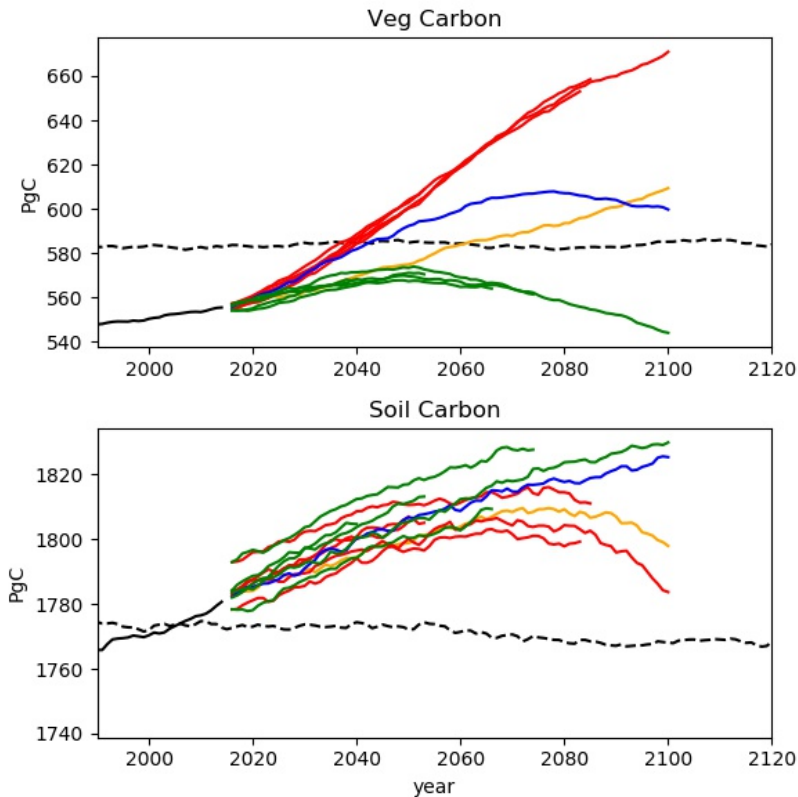
Hist ensemble (red)

Hist-LandUse-only (green)



# ssp370-ssp126-lu vs ssp370

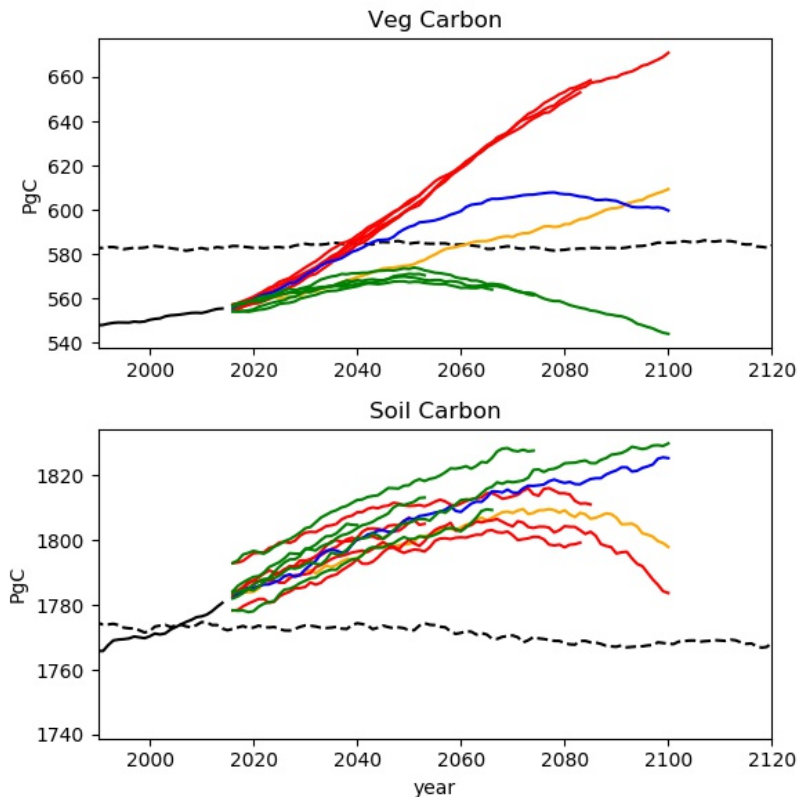
- Vegetation carbon timeseries [BLUE vs GREEN CURVES]



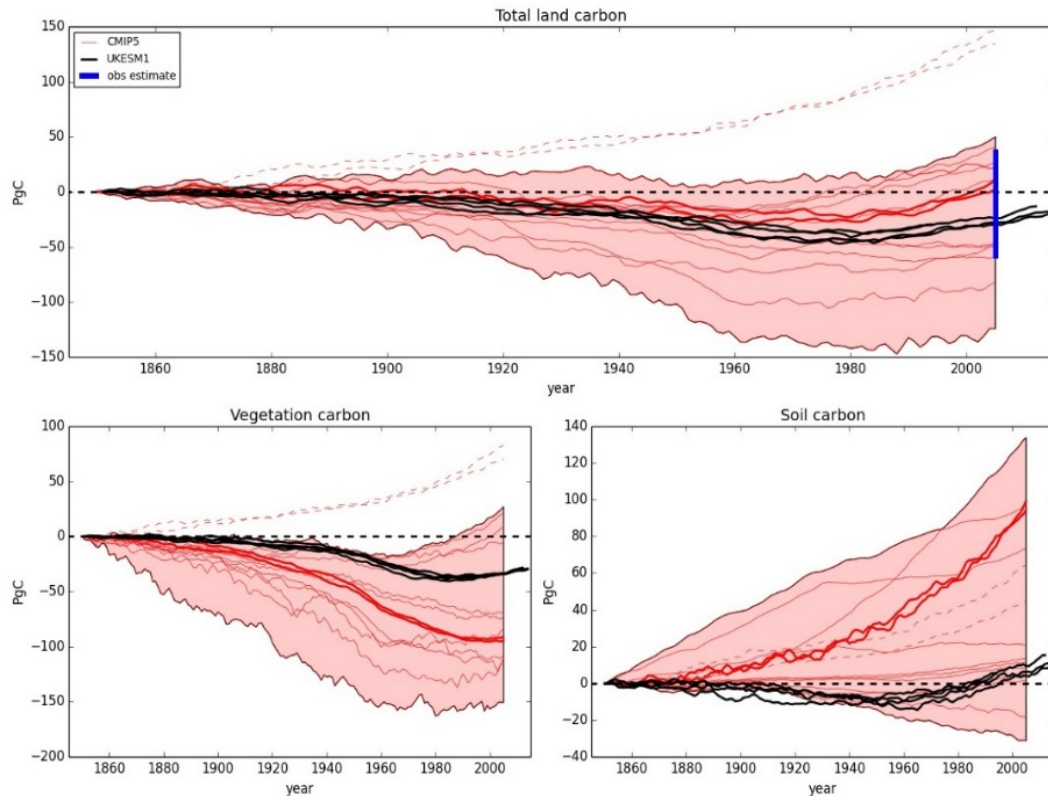


# Met Office ssp370-ssp126-lu vs ssp370

- Vegetation carbon timeseries from [RED and YELLOW CURVES]



# Historical Scenario - C uptake : Land

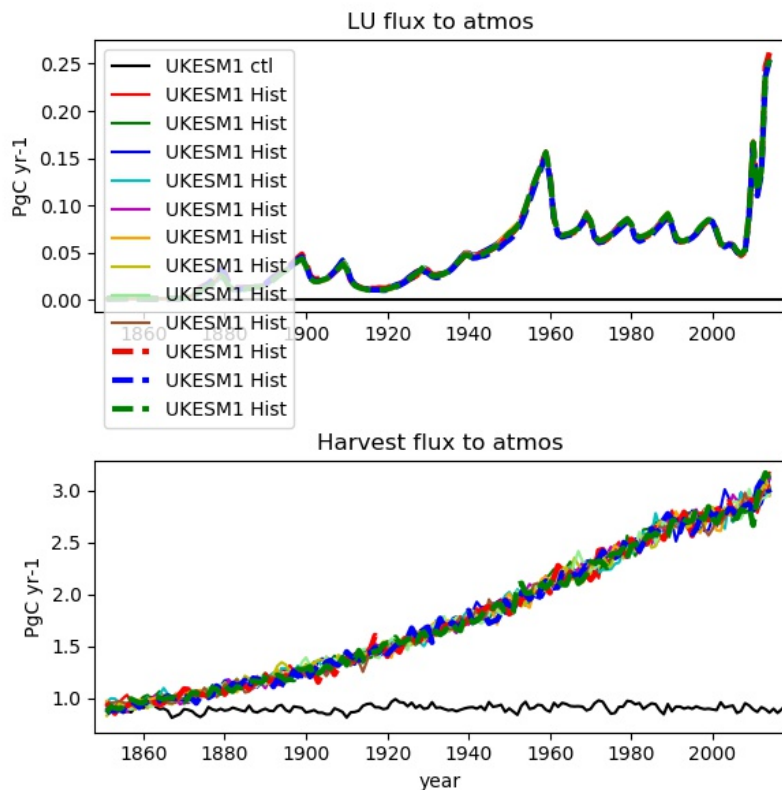


- Historical land carbon uptake is the net effect of two processes:
  - Land-use change: deforestation, regrowth
  - Climate and CO<sub>2</sub> impacts on undisturbed vegetation
- UKESM is doing a good job of getting the historical land sink within observational estimates
  - Changes in UKESM veg / soil much less than HadGEM2ES:
    - 13PFTs vs 5PFTs
    - N limitation of vegetation growth
  - In UKESM harvest C flux is removed
    - would have gone into soil C in HadGEM2ES.

# Simulated historical land use emissions

Accurate simulation of historical LULCC emissions requires more than 1850 → 2015 experiment

- captures flux from harvest and deforestation...
- ...but neglects carbon taken up by regrowth of natural vegetation on abandoned agricultural land
- comparison of land carbon store **historical** vs **hist-noLu** captures all three



Land Use emissions from decay of cleared trees / shrubs

Harvest Flux

piControl ~ 0.9GtC/yr

Green: Observations

Blue: Difference in land  
carbon store:  
[Hist – Hist-noLu]

Red: Interactive LU  
emissions in esm-Hist  
(relative to esm-  
piControl)

