

UKESM Overview & Status

UKESM development team, GC development team and many collaborators

The Earth System

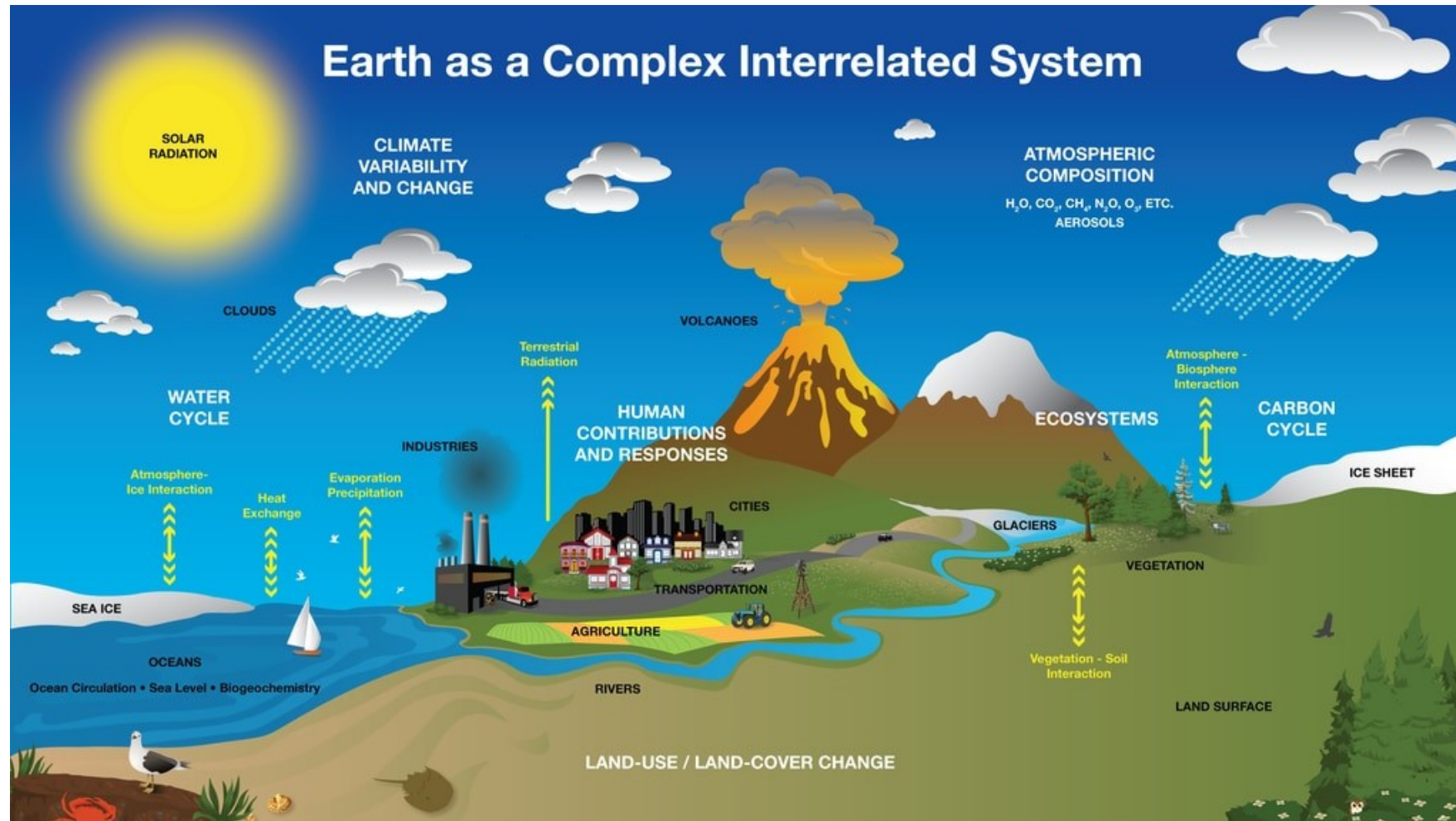


Image:
NASA's
Goddard
Space Flight
Center

Earth system models represent both the physical climate and carbon cycle, as well as other important components of the coupled Earth system e.g. atmospheric chemistry, aerosols, vegetation, marine biogeochemistry, cryosphere

What is UKESM?



 Met Office

 Natural Environment Research Council

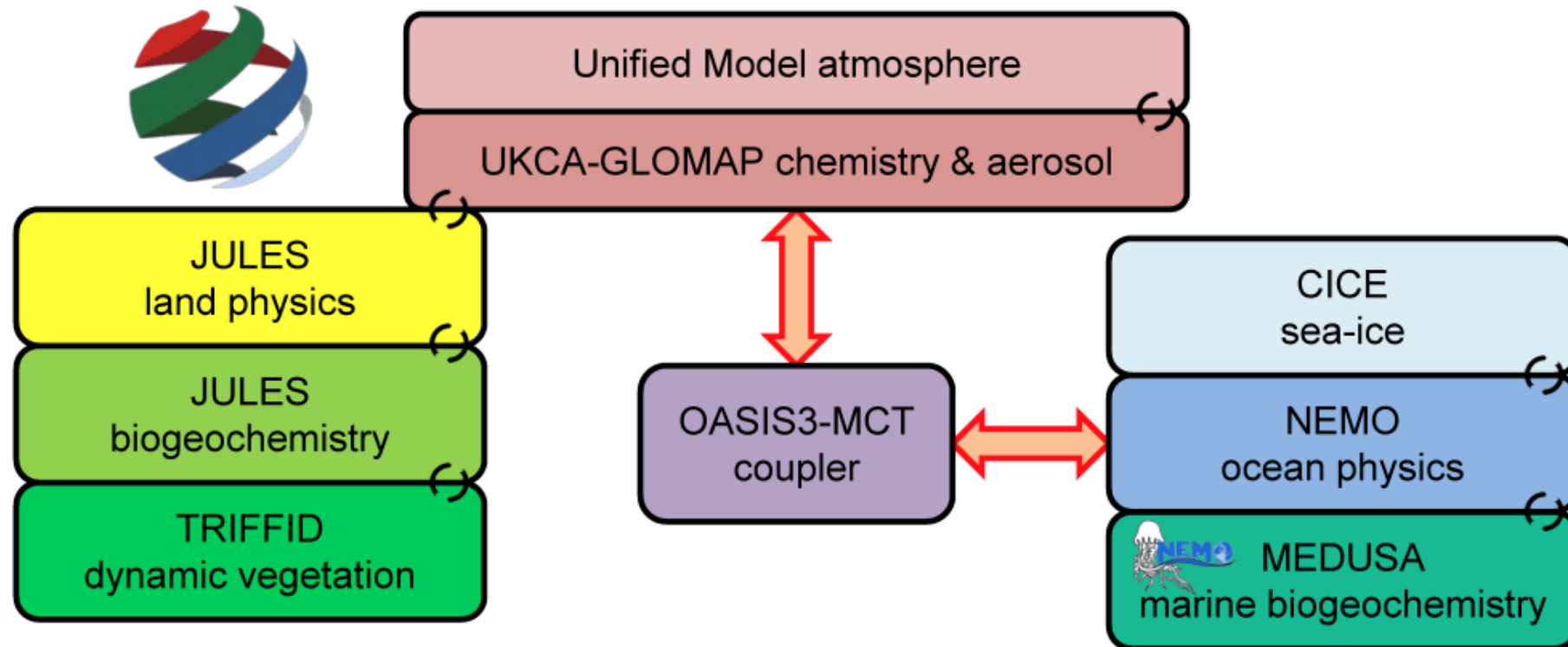
- UKESM is the UK's Earth System model jointly developed by the Met Office and NERC.
- UKESM1 consists of the HadGEM3 global coupled physical climate model plus additional components that model key biogeochemical, chemistry, aerosol and vegetation and cryosphere processes.
- UKESM1 released to the community in 2019 and provided a significant part of the UK's contribution to CMIP6.
- In 2023 an updated version UKESM1.1 was released.
- UKESM2 under development – aiming for freeze early 2026.

UKESM1 Overview



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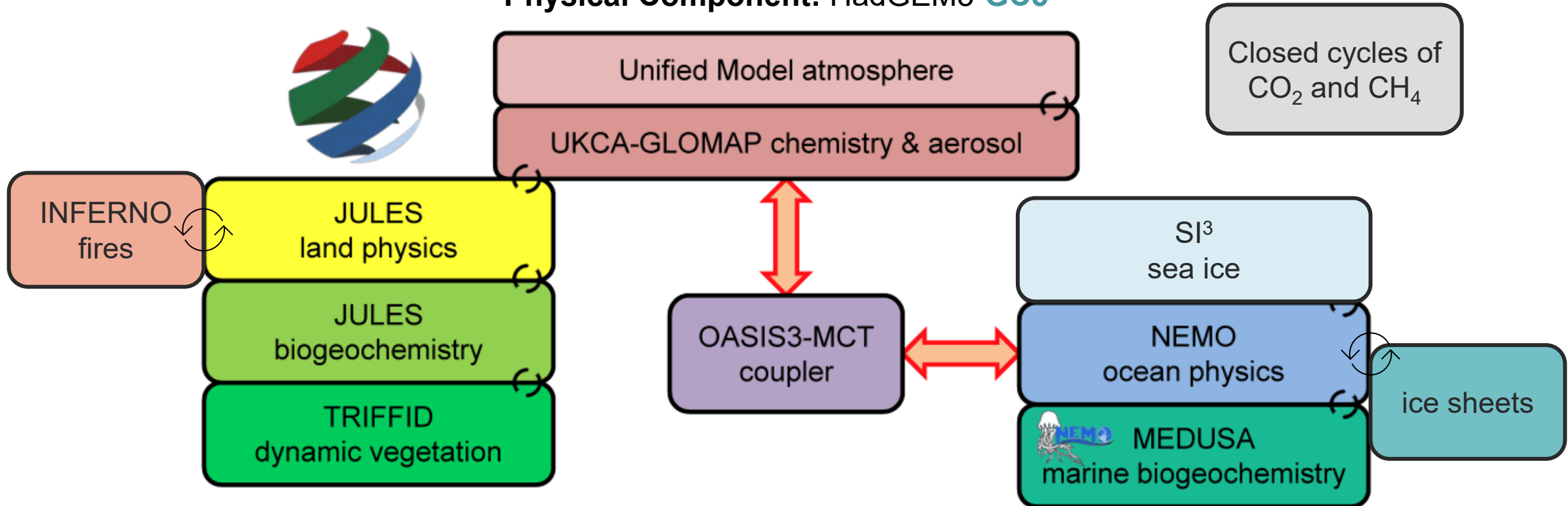
UKESM2 Overview



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Physical Component: HadGEM3-GC5



UKESM2 Key New Science Capability



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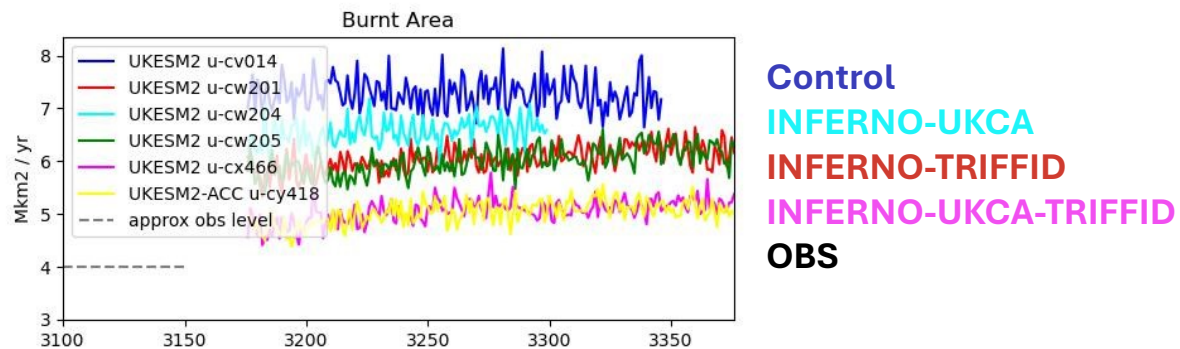
Science level of maturity

- Emission-driven configuration for both CO₂ and CH₄
- Interactive fire; coupled to atmospheric composition & carbon-cycle + dynamic vegetation
- GC5-central physical model
- Interactive ice sheets for Greenland and Antarctica
- Thermal acclimation of photosynthesis
- Package of UKCA composition improvements
- Permafrost coupled to C and N cycle

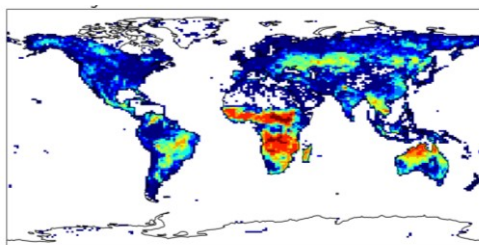
Interactive fire



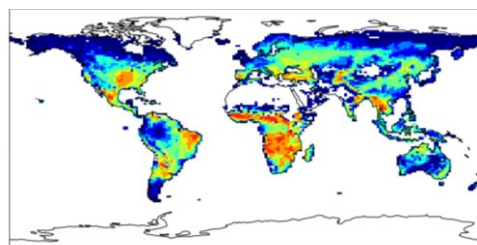
INFERNO: Interactive Fires and Emissions algorithm for Natural environments Coupling fire to vegetation dynamics, carbon cycle and atmospheric composition



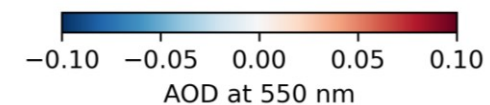
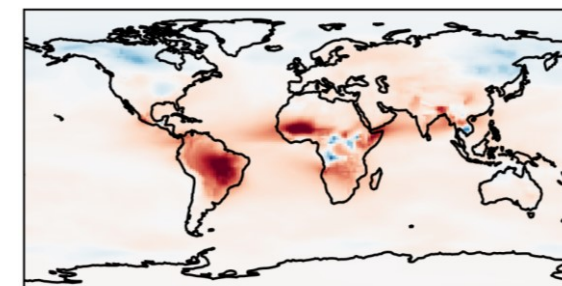
Observations: GFED4 (PD)



UKESM2 proto (PI)

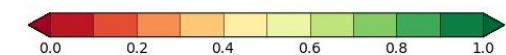
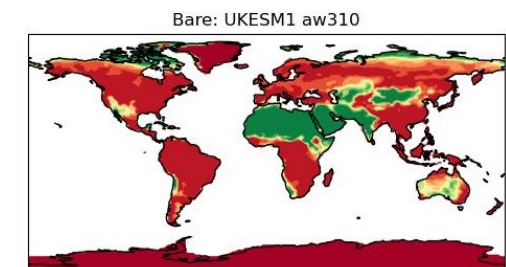
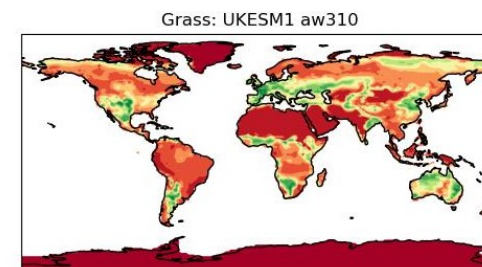
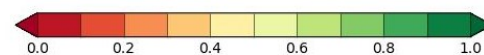
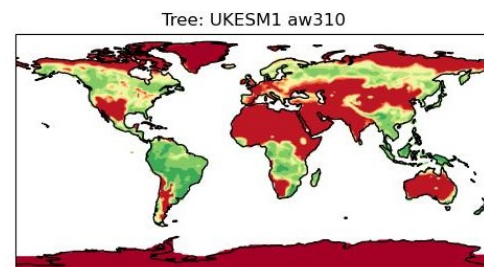
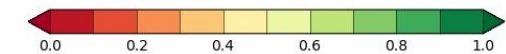
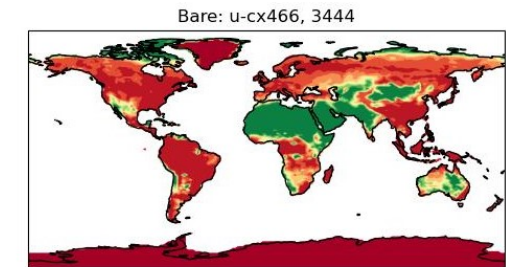
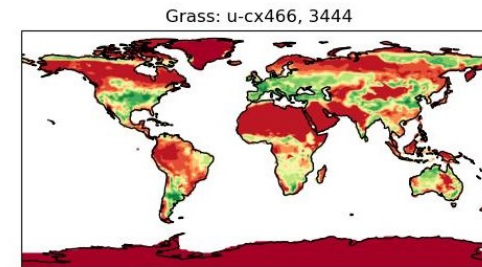
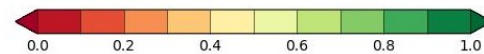
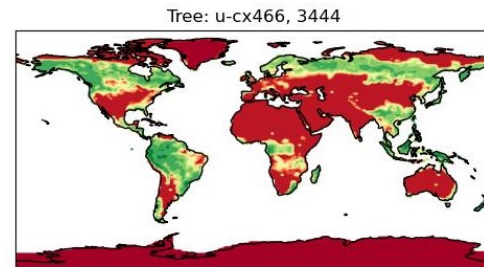


Change in AOD



INFERNO: Interactive Fires and Emissions algorithm for Natural environments Coupling fire to vegetation dynamics, carbon cycle and atmospheric composition

- Reduced tree cover in Africa and NE South America, replaced by grasses
- Higher tree cover in northern high latitudes, instead of grasses
- A bit more bare soil in Africa and Australia with fire

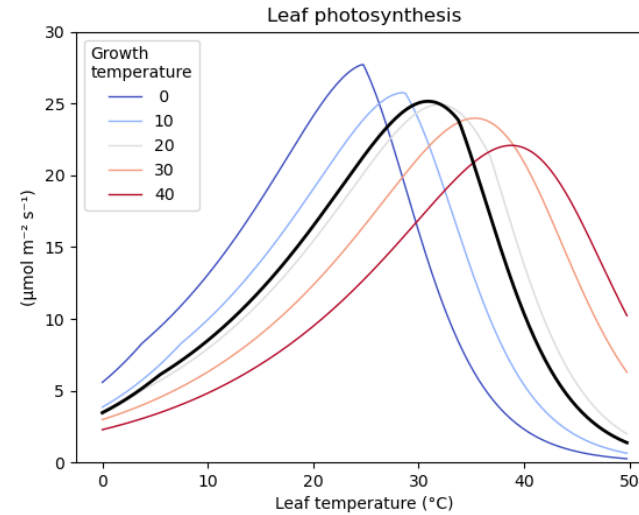


Thermal acclimation scheme

Acclimation: a change in the relationship between photosynthetic rate and leaf temperature in response to short-term (days, weeks) ambient temperature

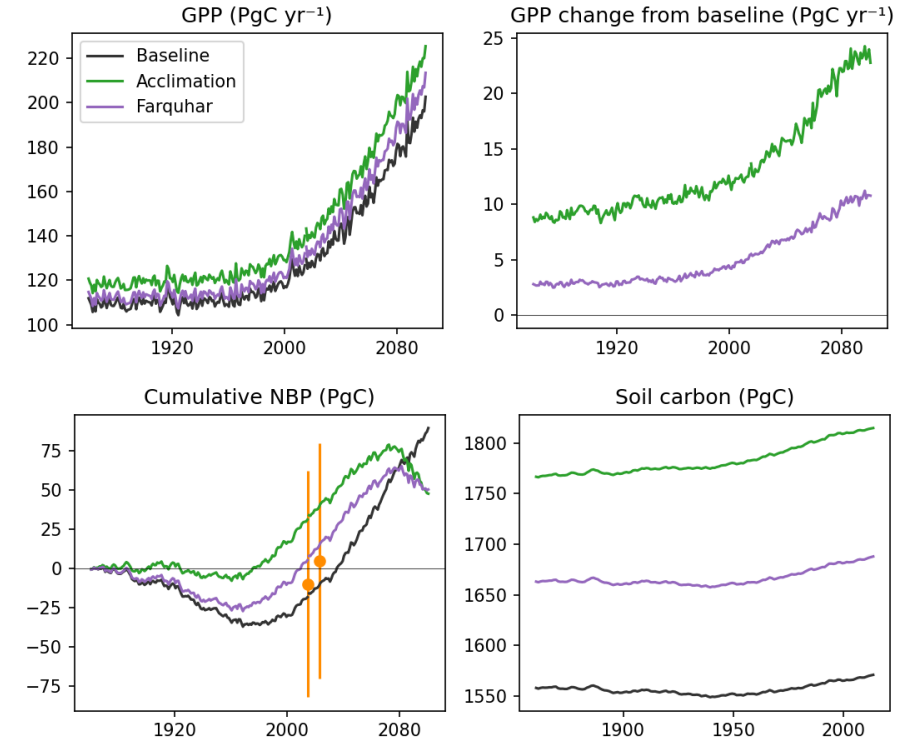
Adaptation: geographical variation in the relationship between photosynthetic rate and leaf temperature that's correlated with long-term (decades) ambient temperature

Kumarathunge et al (2019)



- **Farquhar photosynthesis model**
- C3 vegetation only
- 5 parameters: H_{aP} , H_{aV} , r_{JV25} , ΔS_p , ΔS_V
- Parameters calculated from dynamic growth temperature and static home temperature:
 - $X = a + b T_{growth} + c T_{home}$
- Growth temperature uses 30-day exponential running mean

Carbon cycle impacts

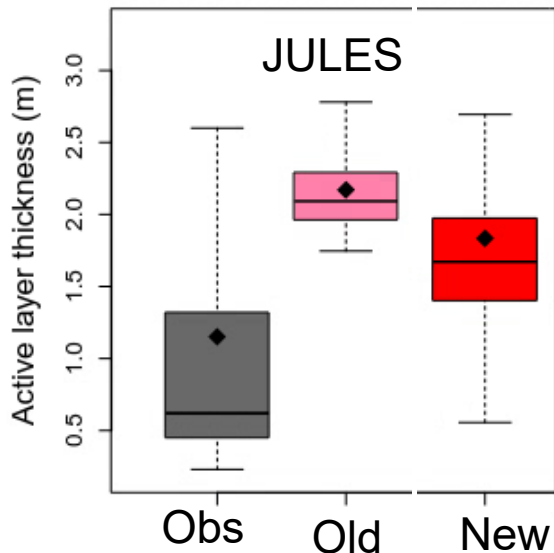


- Greater global photosynthesis (GPP) and carbon stocks
- Changes to net land sink (NBP)

Permafrost improvements

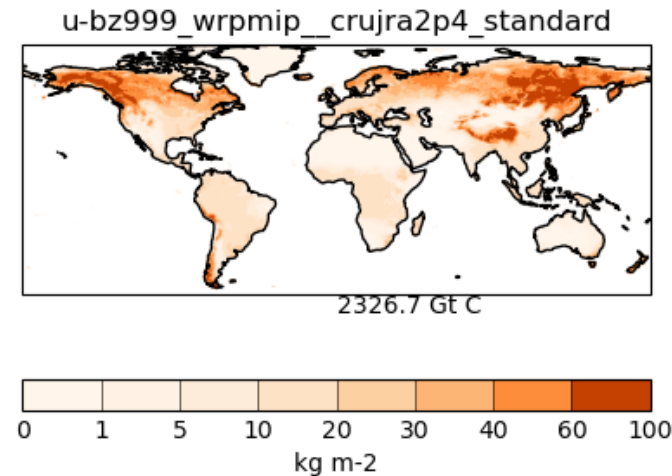
Fairly mature in JULES and technically present in UKESM
Needs parameterisation, tuning and spinup

Increase soil depth & no. soil levels
10 layers up to 10.5 m total depth



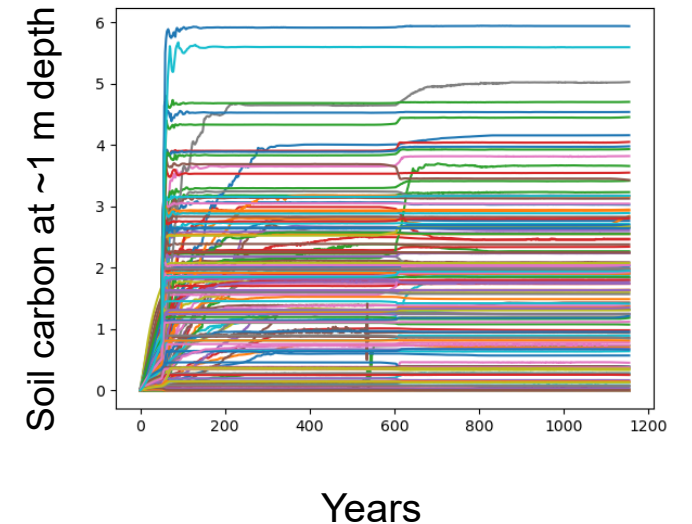
Improve model maximum summer thaw depth

Layered soil carbon
JULES



More soil carbon in Arctic as observed

Method to accelerate spinup
(Samar Khatiwala)



Quicker spinup for soil carbon
(typically need up to ~70,000 years)

Summary



 Met Office

 Natural Environment Research Council

- Key new science capability (e.g.: interactive fire, nitrate aerosol, emission-driven CO₂ and CH₄) is at advanced stage of development and are being tested now in coupled UKESM2 prototype.
- UKESM2 freeze expected early 2026 and will feed into CMIP7 community MIPs.
- Ambition to include as many interactive couplings in UKESM as possible where coupled feedbacks are important in future projections.

UKESM1.3



Met Office



UKESM1.1

UKESM1.3

UKESM1.1 (Mulcahy et al, 2023)

plus

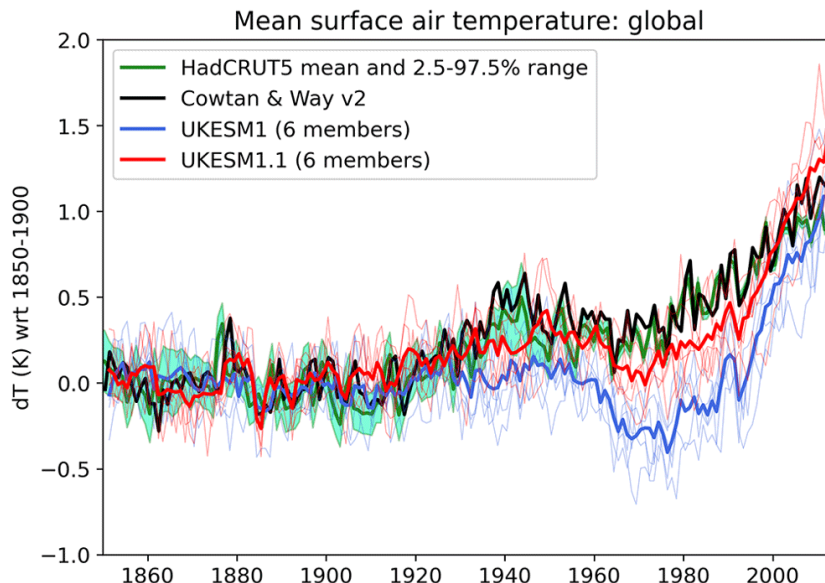
Emission-driven CO₂ and CH₄

Interactive ice-sheets

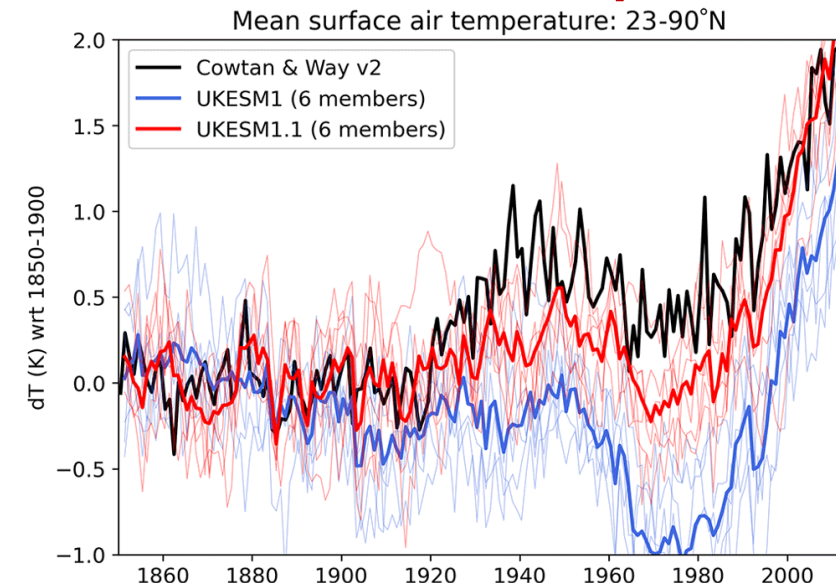
Currently running variant of this

(CH₄ emissions not included)

GLOBAL SAT



Northern Hemisphere



Significant improvement in the historical GMST record.

EffCS = 5.3K