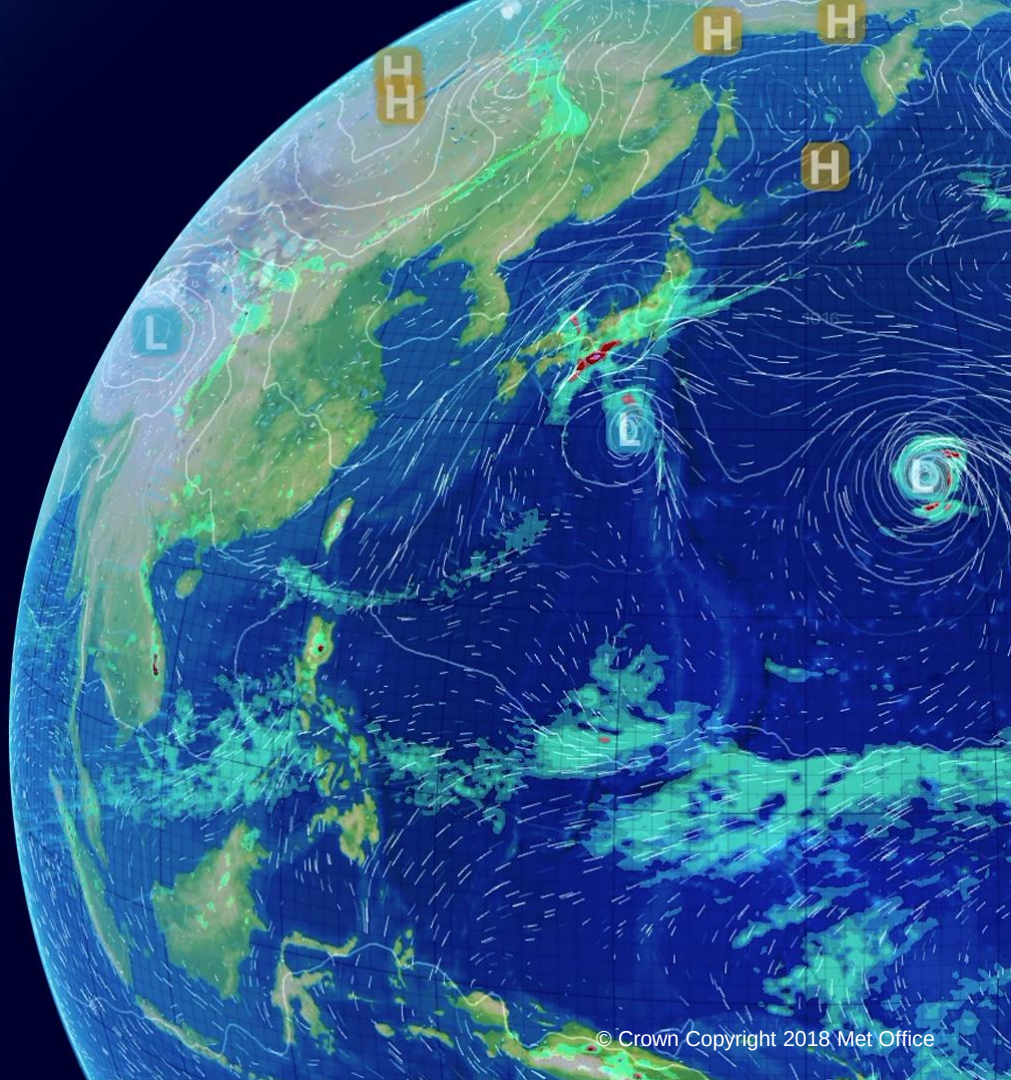
JULES in UKESM1: an example of supported configuration

Chris Jones + many others

JULES 2018 science meeting



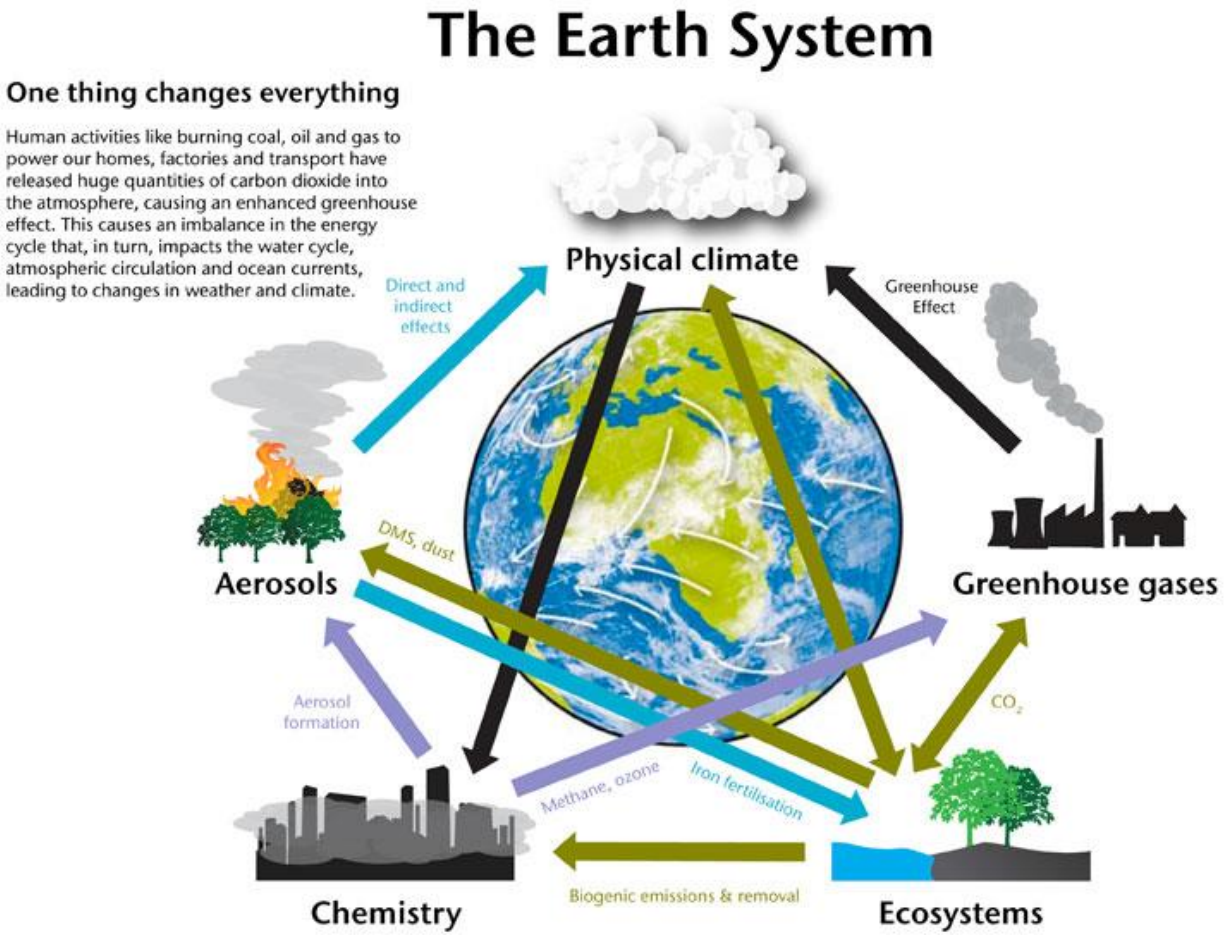
UKESM1

- First official configuration of the UK Earth System Model
  - A joint NERC-Met Office activity to build coupled climate/earth system model
  - Successor to HadGEM2-ES
  - Will contribute main UK contribution to CMIP6 modelling activity for next IPCC Assessment Report

- JULES-ES is the land-surface model within it
  - Fruit of 5+ years of effort to develop, build, configure, test, tune and couple
  - Now running operationally in UKESM1

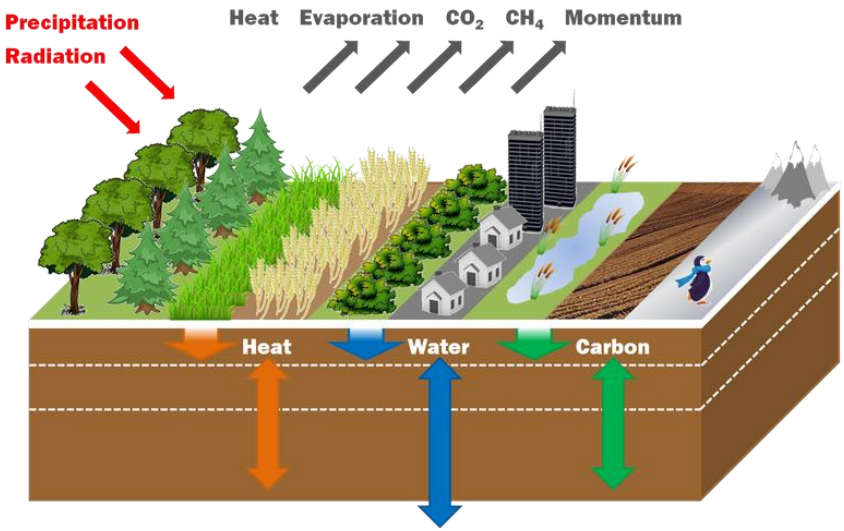
Met Office

The ‘Earth System’ differs from the ‘Physical’ model in that includes amongst other things biogeochemical interaction and feedbacks.



JULES-ES

- JULES-ES is the terrestrial earth system component of UKESM (excluding ice sheets).
- JULES-ES simulates the exchange of heat, water, momentum, carbon, methane and BVOCs between the land and atmosphere
- At the core is the JULES physical land setup (JULES-GL7) with additional processes such as TRIFFID enabled which otherwise would be input from ancillary.



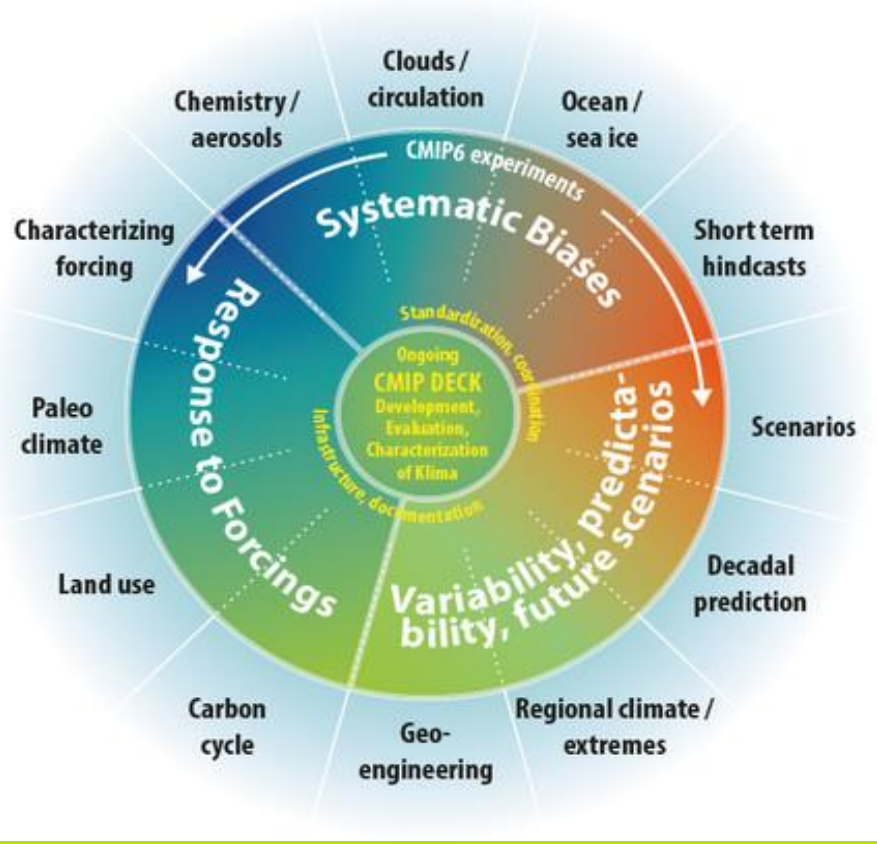
Why this talk?

- As part of JLMP the plan is that JULES-ES 1.0 will be released to the community in the coming months
- This talk is to showcase what it can do, and the importance of key configurations
  - e.g. "GL" doesn't have carbon cycle or veg dynamics enabled.
  - Can’t just turn on switches and hope for the best…
  - JULES out-of-the-box +TRIFFID + N-cycle is not a scientifically meaning set-up – has taken years to get it right
- future ES applications can start from here and develop from this base.
  - e.g. adding more nutrients, wetlands/methane, fire etc etc

- JULES out-of-the-box ≠ JULES-ES

When is it running?

- Now – will contribute to CMIP6 over the next few years
- Land-focused “MIPs” include carbon cycle land-use, and surface processes



Who is it for?

- Everyone
- Represents the UK science community
  - NERC + MetOffice land modellers and climate modellers
  - JULES offline and UKESM coupled
  - Results available to all for analysis
  - Configuration available to all to do own science

Some sample results

- LUMIP, LS3MIP coming soon
- C4MIP – very early results now available
  - Coupled climate carbon cycle intercomparison
  - Motivation is to understand feedbacks between climate and carbon cycle
  - To enable planning of carbon budgets to achieve climate targets such as Paris Agreement 2-degree (1.5 degree) ambitions.
  - (Almost) all CMIP5 models neglected land nitrogen cycle and therefore had persistent overestimate of land carbon uptake – CMIP6 must address this…

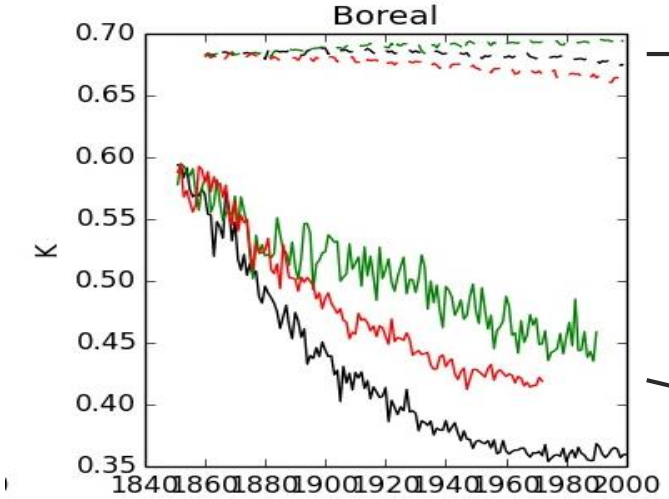
Met Office

N-cycle especially affects partitioning and allocation of carbon

- Define CUE = carbon use efficiency = NPP:GPP ratio
- Availability of nutrients affects how much GPP can be allocated to biomass
- Expect interactive N-cycle to significantly affect this
  - Better initial simulation
  - Changes into the future

Boreal zone especially of interest

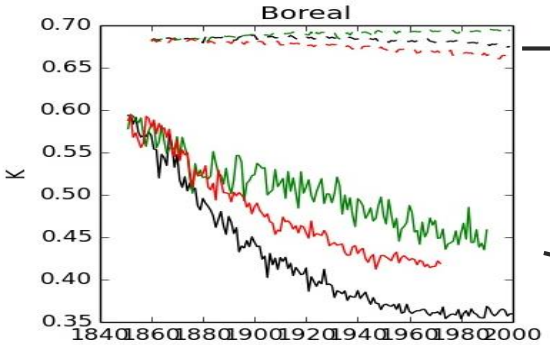
- HadGEM2-ES showed very little change in CUE
- UKESM1 simulates huge decrease – both for increased CO2 and for climate warming.



HadGEM2-ES

UKESM1

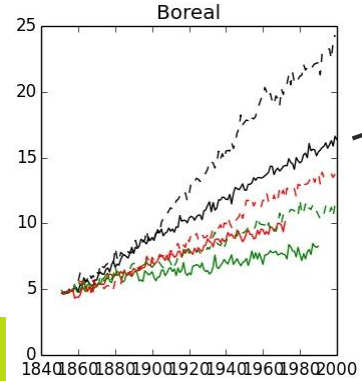
Boreal zone especially of interest



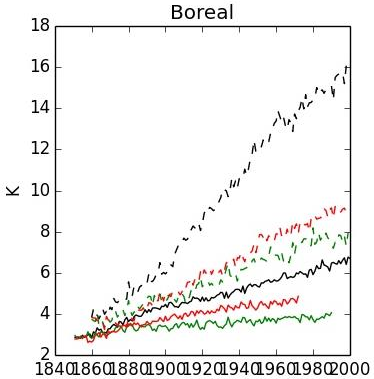
HadGEM2-ES

UKESM1

- Therefore NPP increases are much less relative to GPP



GPP increase a bit smaller than HadGEM2

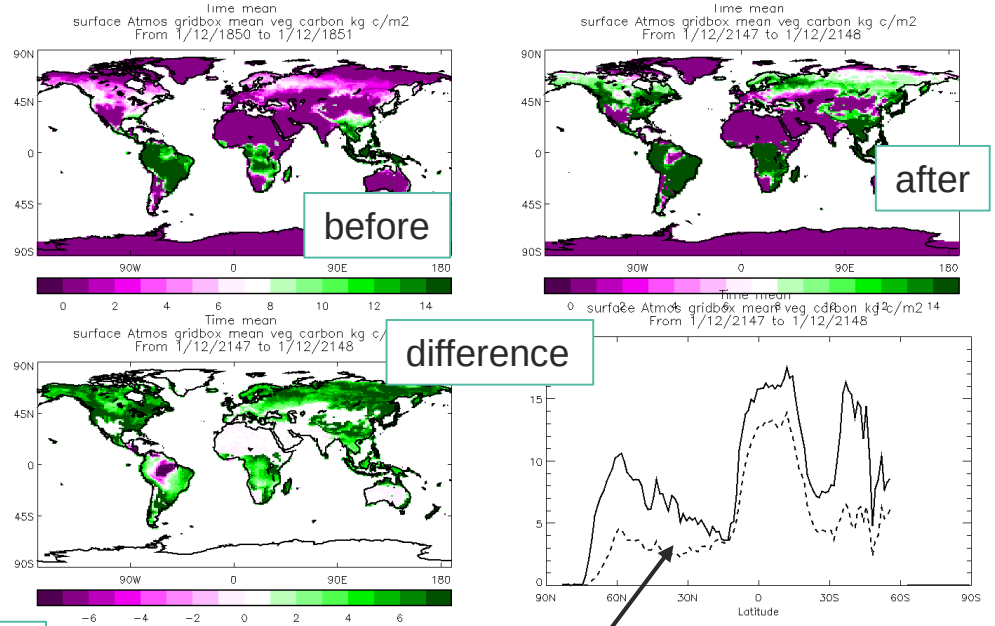


NPP increase a **lot** smaller than HadGEM2

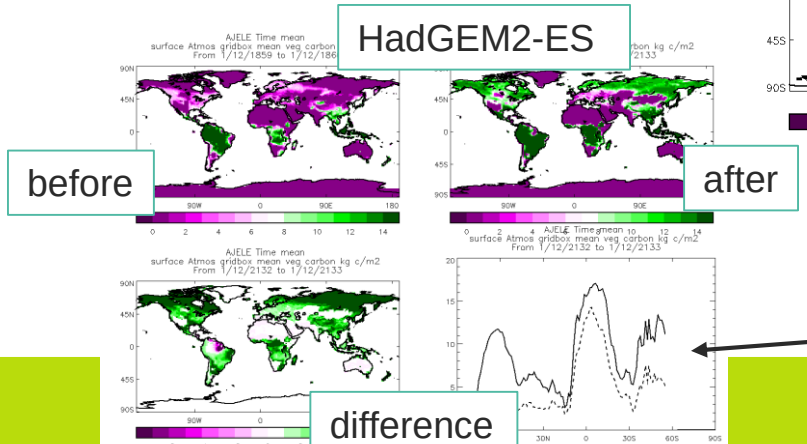
Regional patterns

- Combined N-cycle and new PFTs
- 300 years of 4xCO2 (i.e. very high, long-term forcing)
- Initial look at veg and soil carbon changes vs HadGEM2-ES

UKESM1



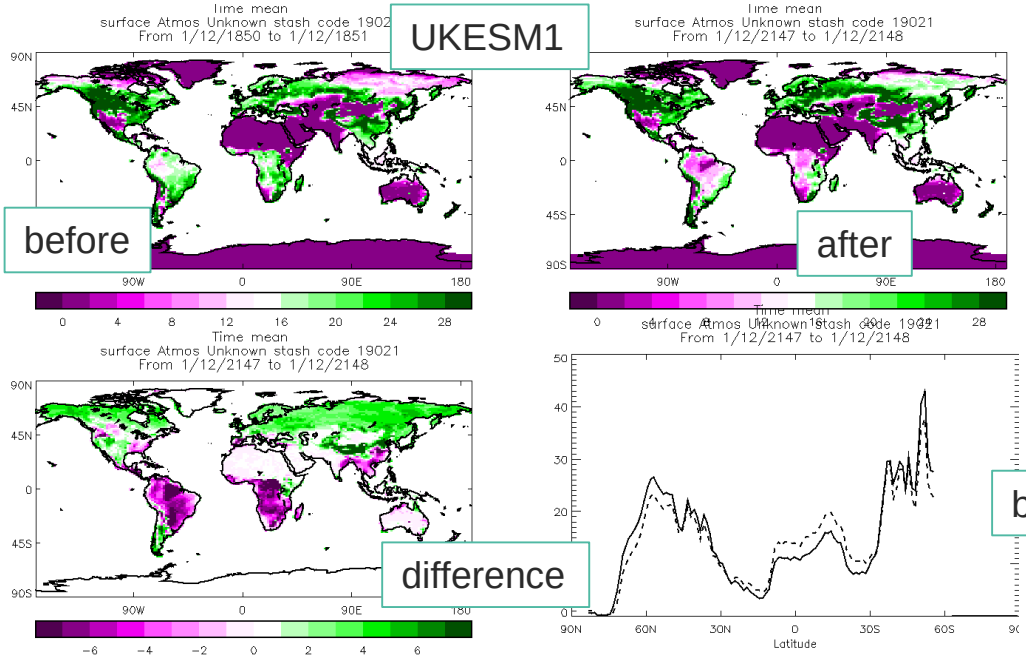
HadGEM2-ES



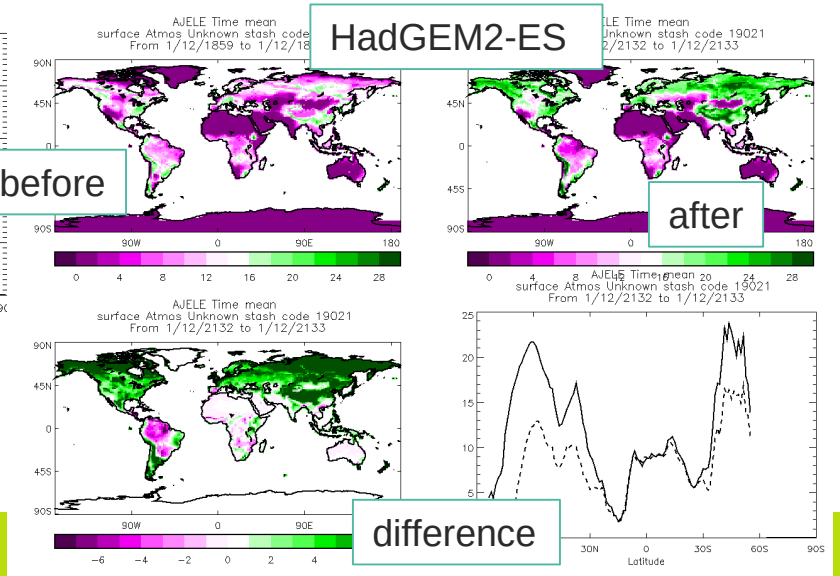
Biomass changes look similar

Regional patterns

- Initial look at veg and soil carbon changes vs HadGEM2-ES



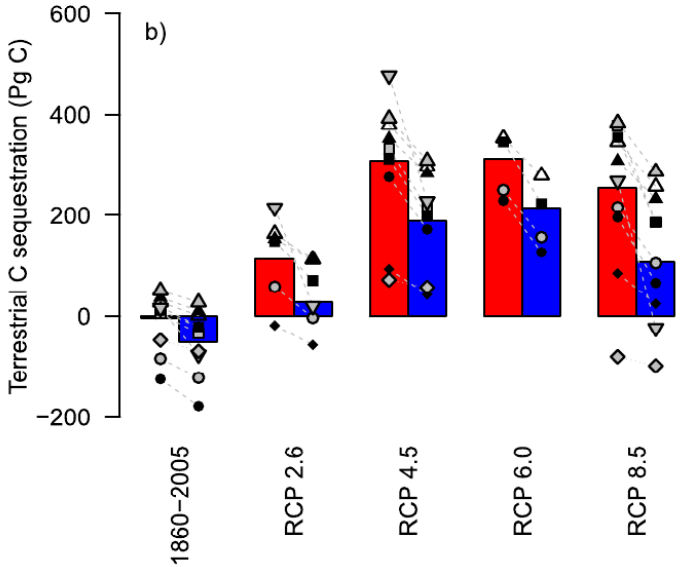
- **Soil carbon very different**
  - **UKESM1 accumulates less**



But is it right?

- CMIP5 accumulated too much carbon

(Zaehle et al 2015; AR5)



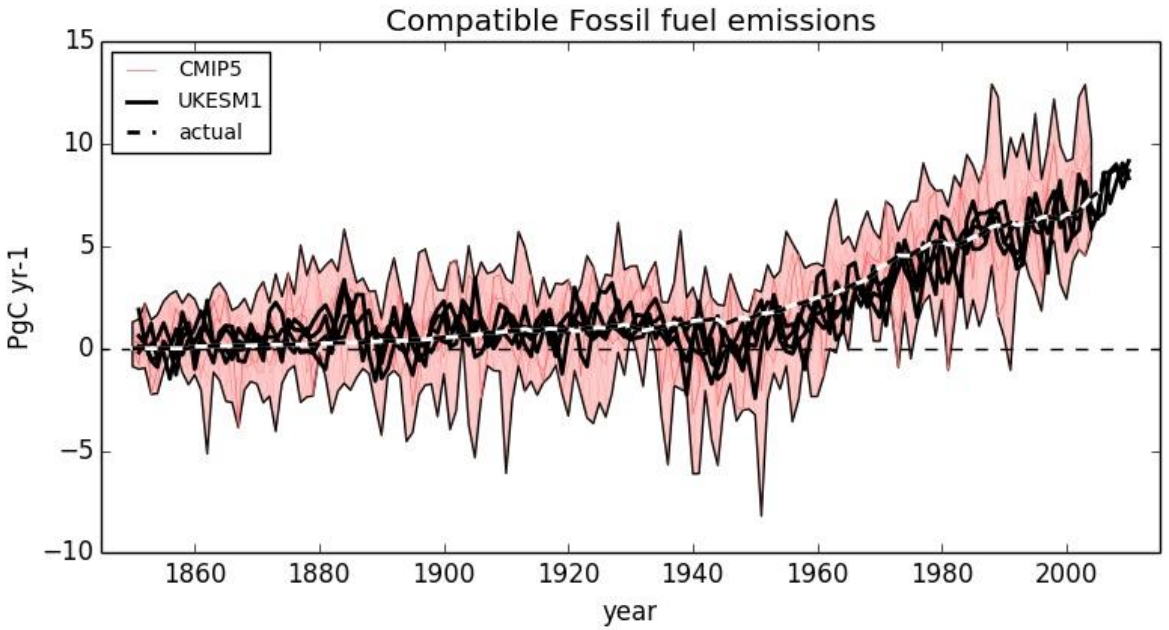
- UKESM1 accumulates less – seems plausible
  - Understanding mechanisms and evaluating why it does this is crucial – key activity within JULES, CRESCENDO, C4MIP

Met Office

Policy relevance?

Carbon budgets

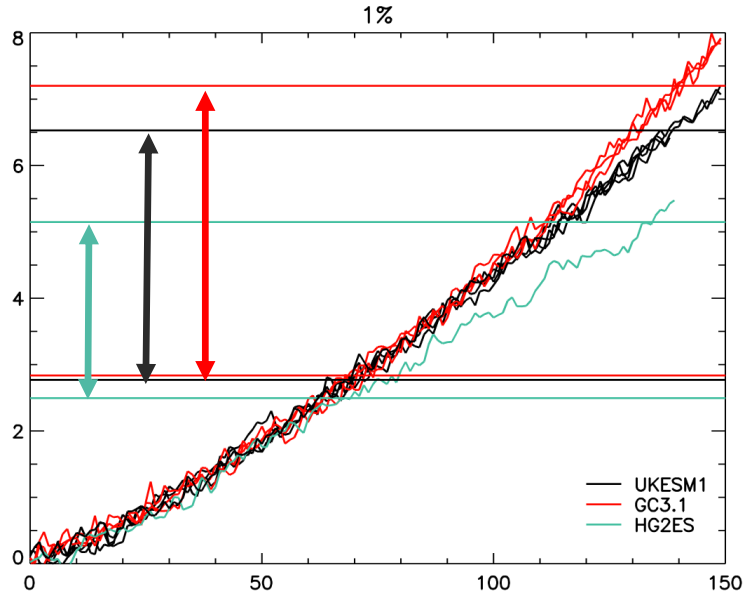
Compatible Fossil Fuel Emissions



- Putting land and ocean sinks together allows us to work out what historical fossil fuel emissions would have been
- To use the model for carbon budget advice relies on us getting this right
- UKESM is doing a good job

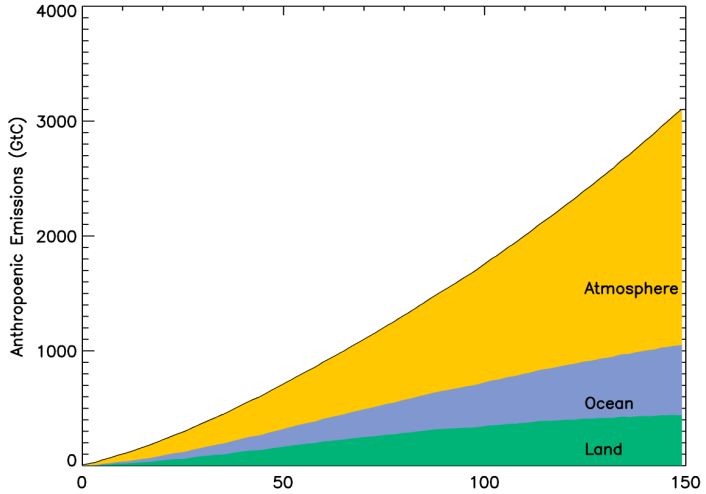
Transient Climate Response

- Idealised 1% experiments
- UKESM has a TCR ~2.6K – slightly warmer than HadGEM2-ES and less than GC3.1
- However, the second doubling in UKESM is substantially larger than UKESM – indicating a stronger forcing/feedback combination in UKESM than HadGEM2-ES.



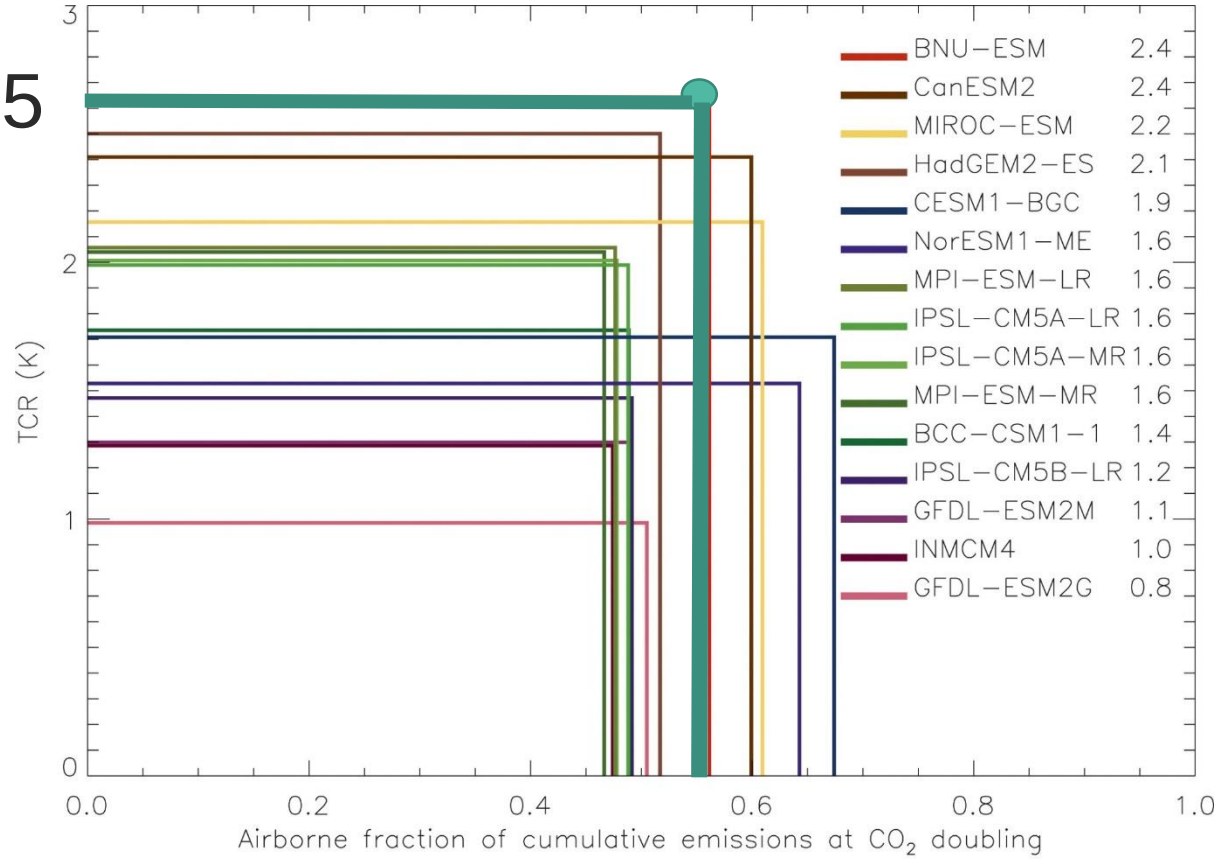
Where does the Carbon go?

- Approximately, half of all emissions remain in the atmosphere – the other half is taken up by the land and oceans.
- However, under climate change the strength of the sink weakens. At 2xCO2 the airborne fraction (AF) is 55% at 4xCO2 AF is 62%
- This is mainly linked to the reduction in the land-borne fraction (LF) which reduces from 22% to 15%. This is partly related to the inclusion of Nitrogen nutrient limitation as well as other feedbacks in the model.



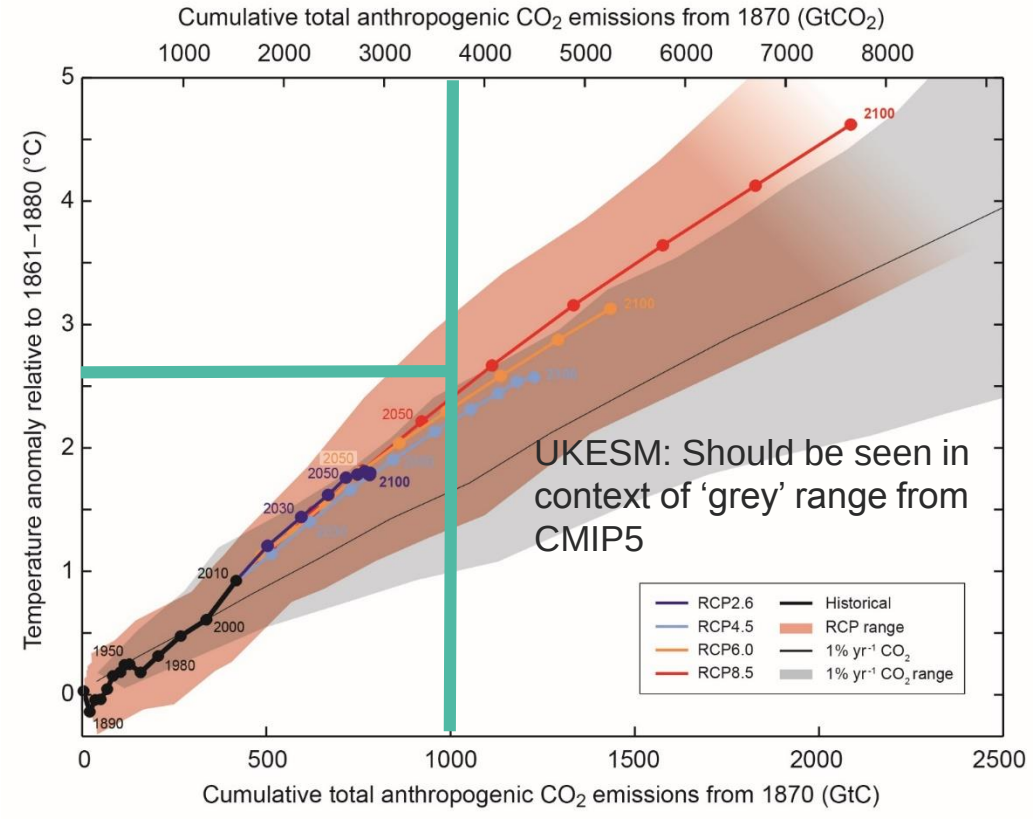
UKESM cf. CMIP5

- UKESM has a high TCR – at the top end of CMIP5 models
- However, the AF is near the middle of the range.
- But what policy makers really want to know is how much warming is expected per unit emission accounting for Carbon Cycle feedbacks….



TCRE

- … this is what is known as the Transient Climate Response to Emissions (TCRE). As standard is given as warming after 1000GtC of CO_2 emissions in a 1% per annum experiments.
- UKESM TCRE ~2.6 k/1000GtC
- HadGEM2-ES – 2.1
- UKESM is outside CMIP5 range primarily due to high TCR.



Other terrestrial BGC

- I haven’t even scratched the surface:
  - Land-use / harvest
  - Wetlands / CH4 emissions
  - Permafrost (improved physics, carbon to come…)
  - BVOCs

- UKESM1 is a big step forward in terrestrial BGC modelling capability and provides a solid foundation for all future work.
  - Further coupling to atmos/ocean: close CH4 and N-cycles
  - Interactive fire / veg-dynamics
  - …

Conclusions

- UKESM1 is a big step forward in terrestrial BGC modelling capability for the UK and provides a solid foundation for all future work.
- New functionality and process understanding built in particularly with the Nitrogen cycle.
- UKESM1 doing a good job of capturing historical carbon budgets.

- JULES-ES available for all: results and set-up
- Take advantage of the huge effort already done to make this a world-leading land-surface model configuration!