

QESM: The QUEST Earth System Model

@Reading: Manoj Joshi, Jonathan Gregory, Annette Osprey,
Allan Spessa, Josh Hooker, Tom Osborne

@CEH Wallingford: Douglas Clark, Eleanor Blyth

@UEA: Erik Buitenhuis, Corinne Le Quéré

@Leeds: Graham Mann, Ken Carslaw

@Cambridge: Luke Abraham, Olaf Morgenstern, John Pyle

@Los Alamos: Rosie Fisher

@Manchester: Rupert Ford, @Met Office: Chris Harris, Ian Culverwell

@Oxford: Josh Fisher, @Lancaster: Oliver Wild

and many others...

Unprecedented attempt to simulate the direction and strength of a wide range of biogeochemical processes and feedbacks affecting the functioning of the Earth system under contemporary and likely future climate scenarios

Coordinated and managed by the NCAS-Climate and the Walker Institute at Reading

Unprecedented attempt to simulate the direction and strength of a wide range of biogeochemical processes and feedbacks affecting the functioning of the Earth system under contemporary and likely future climate scenarios

Coordinated and managed by the NCAS-Climate and the Walker Institute at Reading

Development builds upon the efforts of several existing modelling consortia

<http://www.quest-esm.ac.uk/>

A climate model simulates the physical processes of the atmosphere and ocean. An Earth system model also includes a wide range of **biological and chemical** processes

When external forcing is applied, the additional processes result in climatic **and environmental** changes that basic climate models simply cannot simulate

A climate model simulates the physical processes of the atmosphere and ocean. An Earth system model also includes a wide range of **biological and chemical** processes

When external forcing is applied, the additional processes result in climatic **and environmental** changes that basic climate models simply cannot simulate

- atmospheric ozone changes*
- ocean acidification*
- terrestrial vegetation cover changes*

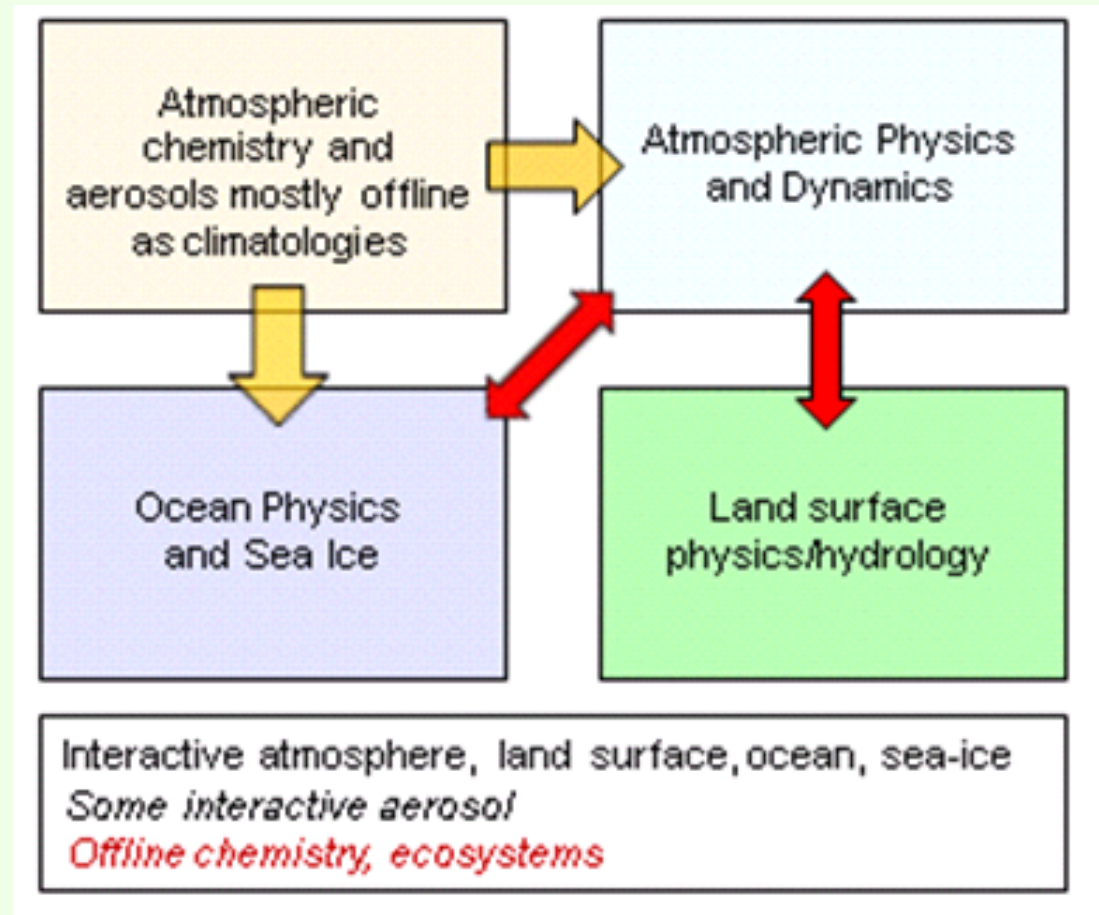
Most climate models consist of the following components:

atmospheric physics

ocean physics

sea-ice

land surface processes



Earth system models consist of the following components:

atmospheric physics

ocean physics

sea-ice

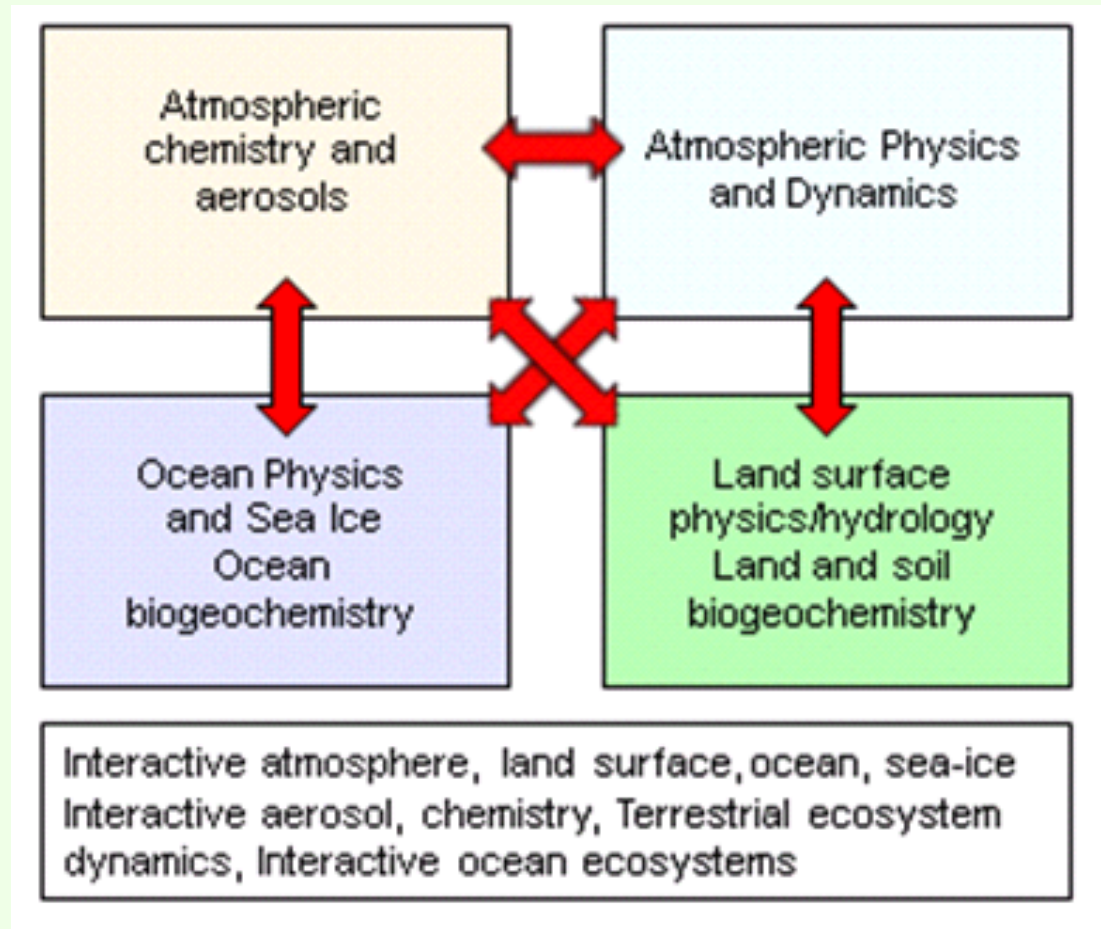
ocean biology

atmos. chemistry & aerosols

land surface processes

dynamic vegetation

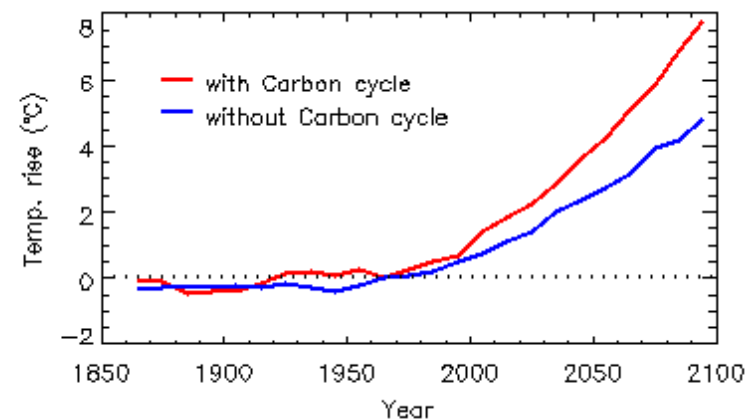
soil carbon



A climate model simulates the physical processes of the atmosphere and ocean. An Earth system model also includes a wide range of *biological and chemical* processes

When external forcing is applied, the additional processes result in climatic *and environmental* changes that basic climate models simply cannot simulate

Projected temperature change in to 2100 when the carbon cycle is **not included**, and **included**
(From Cox et al 2000)



A climate model simulates the physical processes of the atmosphere and ocean. An Earth system model also includes a wide range of *biological and chemical* processes

When external forcing is applied, the additional processes result in climatic *and environmental* changes that basic climate models simply cannot simulate

Rising CO₂ levels

→ Rising O₃ levels

→ decrease in photosynthesis

→ less CO₂ uptake by plants

→ more CO₂ accumulation in the atmosphere (*Sitch et al 2007*)

A climate model simulates the physical processes of the atmosphere and ocean. An Earth system model also includes a wide range of *biological and chemical* processes

When external forcing is applied, the additional processes result in climatic *and environmental* changes that basic climate models simply cannot simulate

Increasing CO₂ changes atmospheric circulation

- Changes dust deposition on ocean surface
- Changes supply of oceanic micronutrients
- changes ocean biological production
- changes CO₂ drawdown

A climate model simulates the physical processes of the atmosphere and ocean. An Earth system model also includes a wide range of *biological and chemical* processes

When external forcing is applied, the additional processes result in climatic *and environmental* changes that basic climate models simply cannot simulate

Added complexity implies significant feedbacks

Previously, each model component treated in a much simpler manner than in state-of-the-art standalone models

Faster computers mean this is no longer necessary

Earth system models consist of the following components:

atmospheric physics

ocean physics

sea-ice

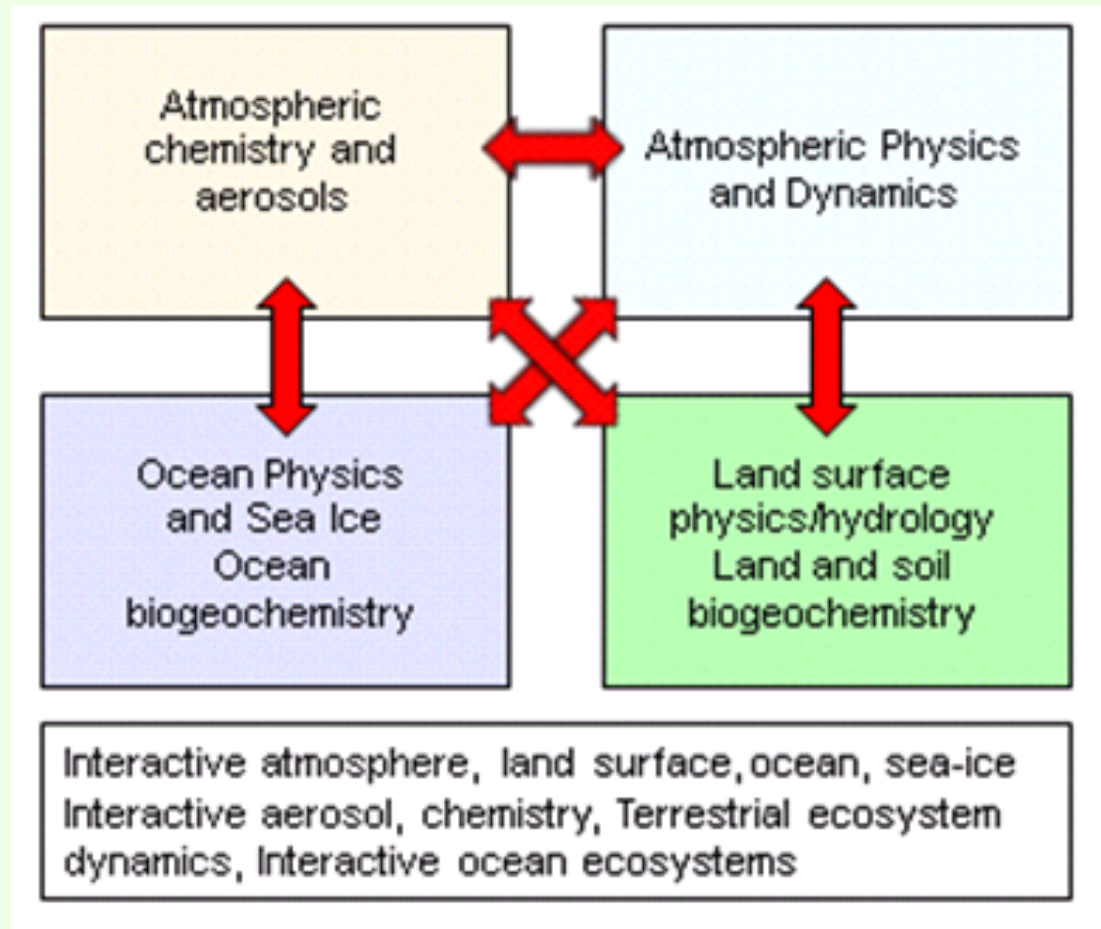
ocean biology

atmos. chemistry & aerosols

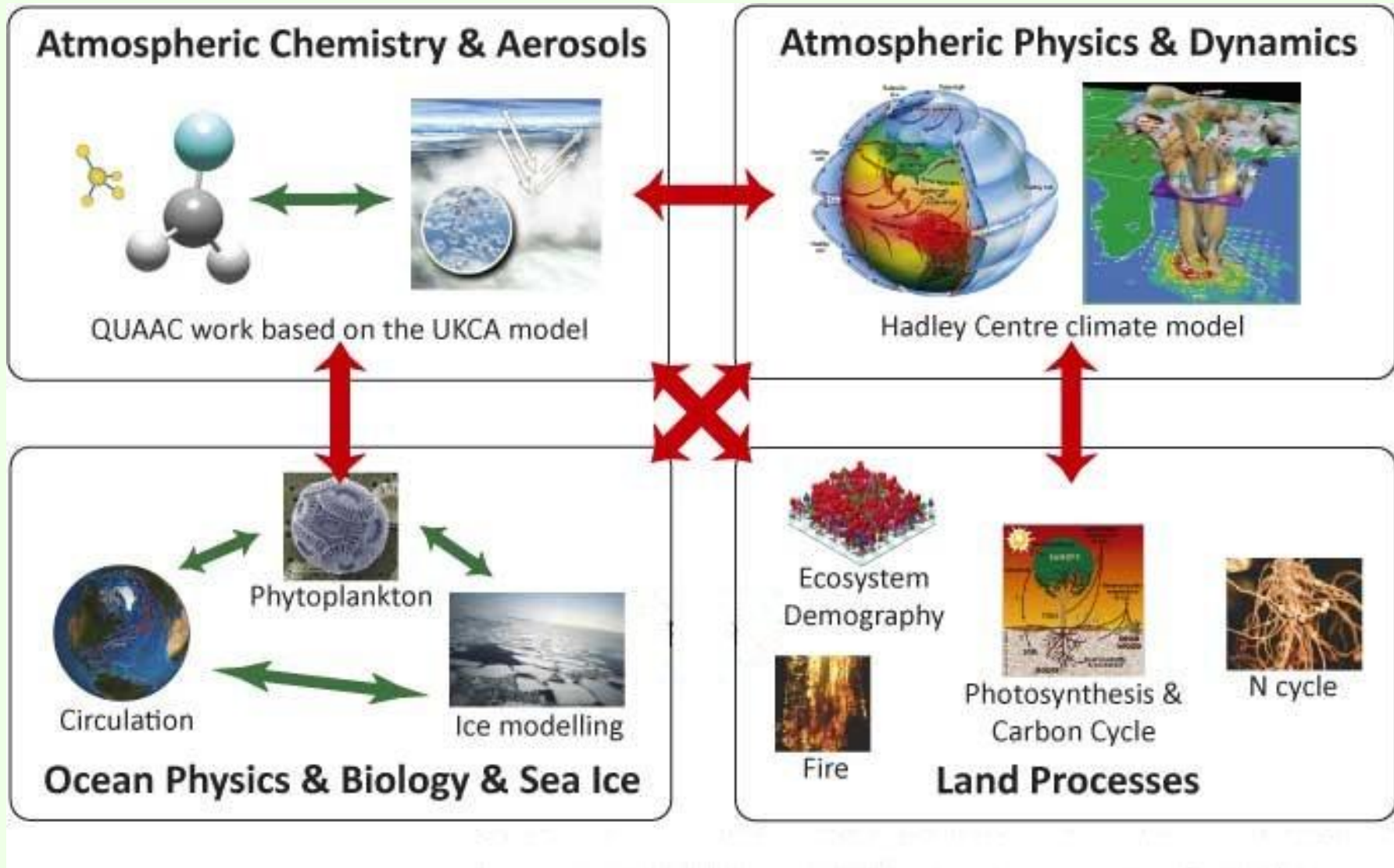
land surface processes

dynamic vegetation

soil carbon



QESM: the QUEST Earth System Model



The QESM is being developed in parallel with the Met Office Hadley Centre's latest climate model HadGEM3-OA

Close relationship in timetable and components

Both ocean and atmospheric components of QESM have half the horizontal resolution of HadGEM3-OA

The QESM is being developed in parallel with the Met Office Hadley Centre's latest climate model HadGEM3-OA

Close relationship in timetable and components

Both ocean and atmospheric components of QESM have half the horizontal resolution of HadGEM3-OA

Atmosphere has 60 layers; resolves stratosphere properly:
increasingly recognised as an important component of projecting extratropical climate change

The UKCA chemistry and aerosol module already runs within the so-called "UM" or Met office Unified Model framework

UKCA was “launched” officially January 2009

QESM will use UKCA-MODE

The UKCA chemistry and aerosol module already runs within the so-called "UM" or Met office Unified Model framework

UKCA was "launched" officially January 2009

QESM will use UKCA-MODE

Have tested UKCA with HadGEM3-A (atmosphere model)

Now testing UKCA/HadGEM3-OA (ocean/atmosphere)

JULES: Joint UK Land Environment Simulator

New science:

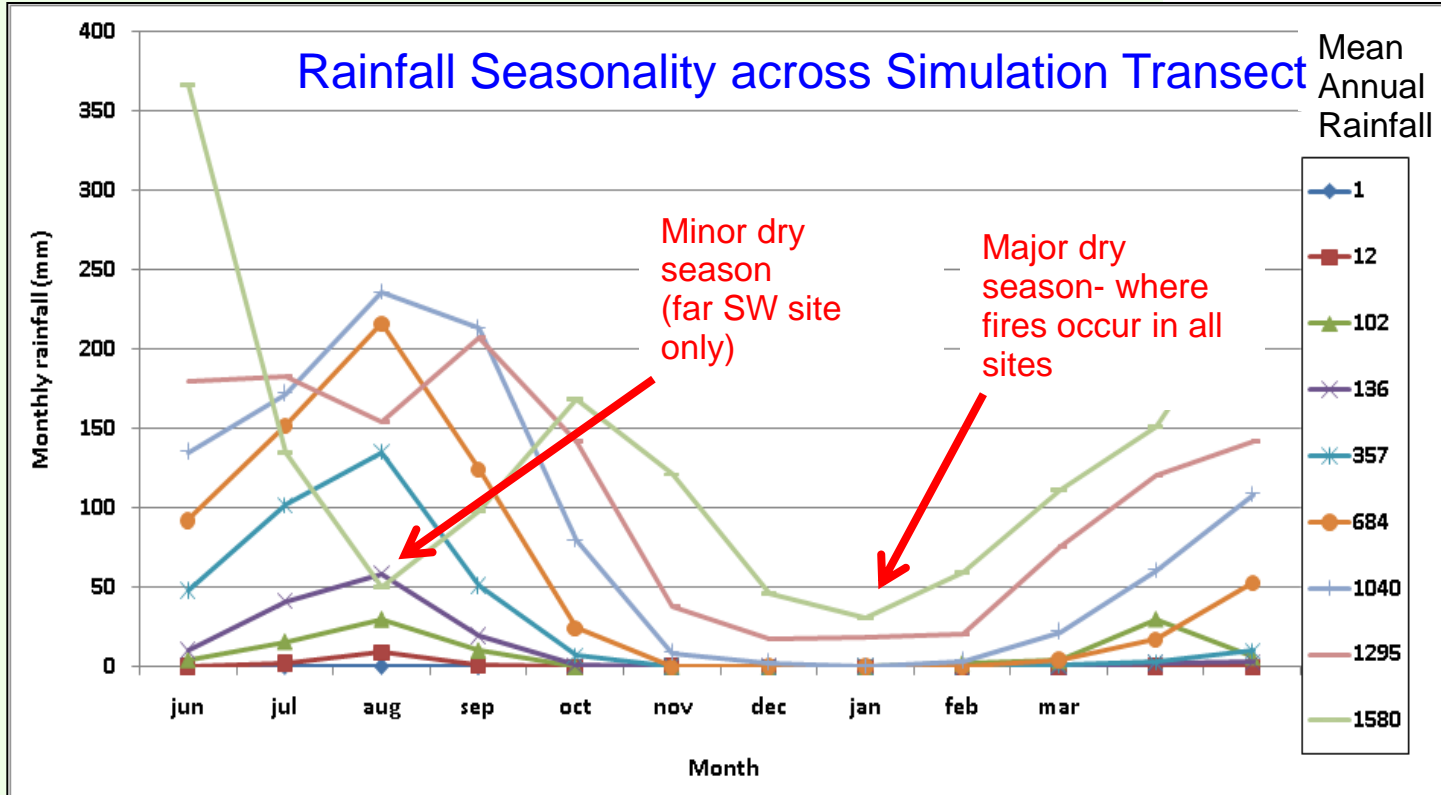
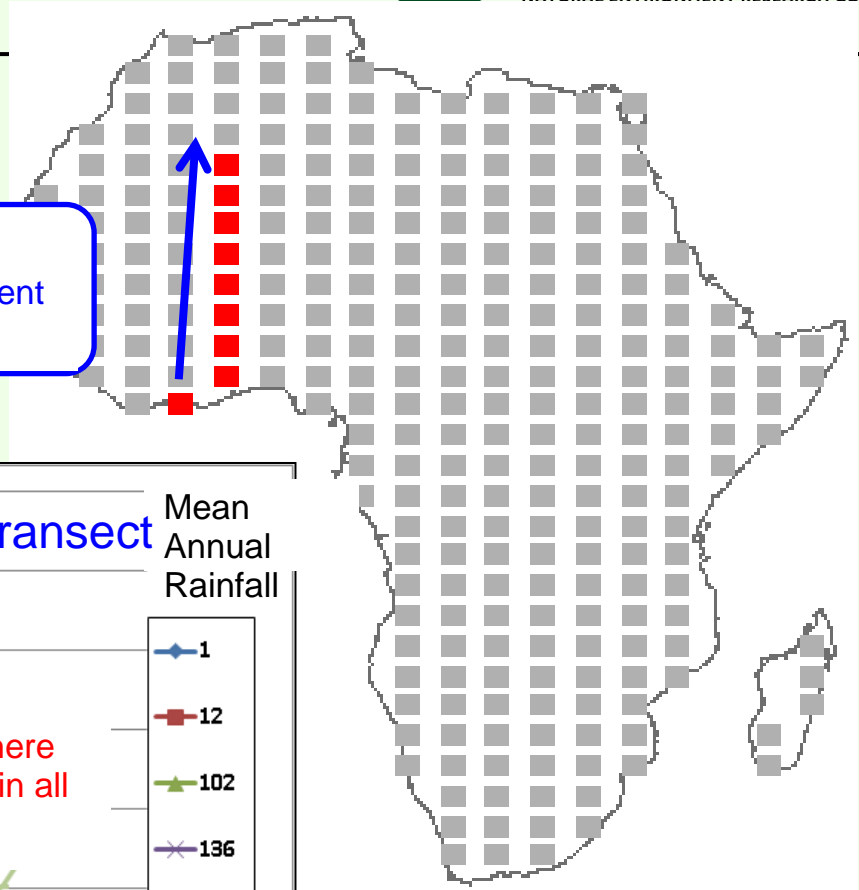
Ecosystem demography and wildfire

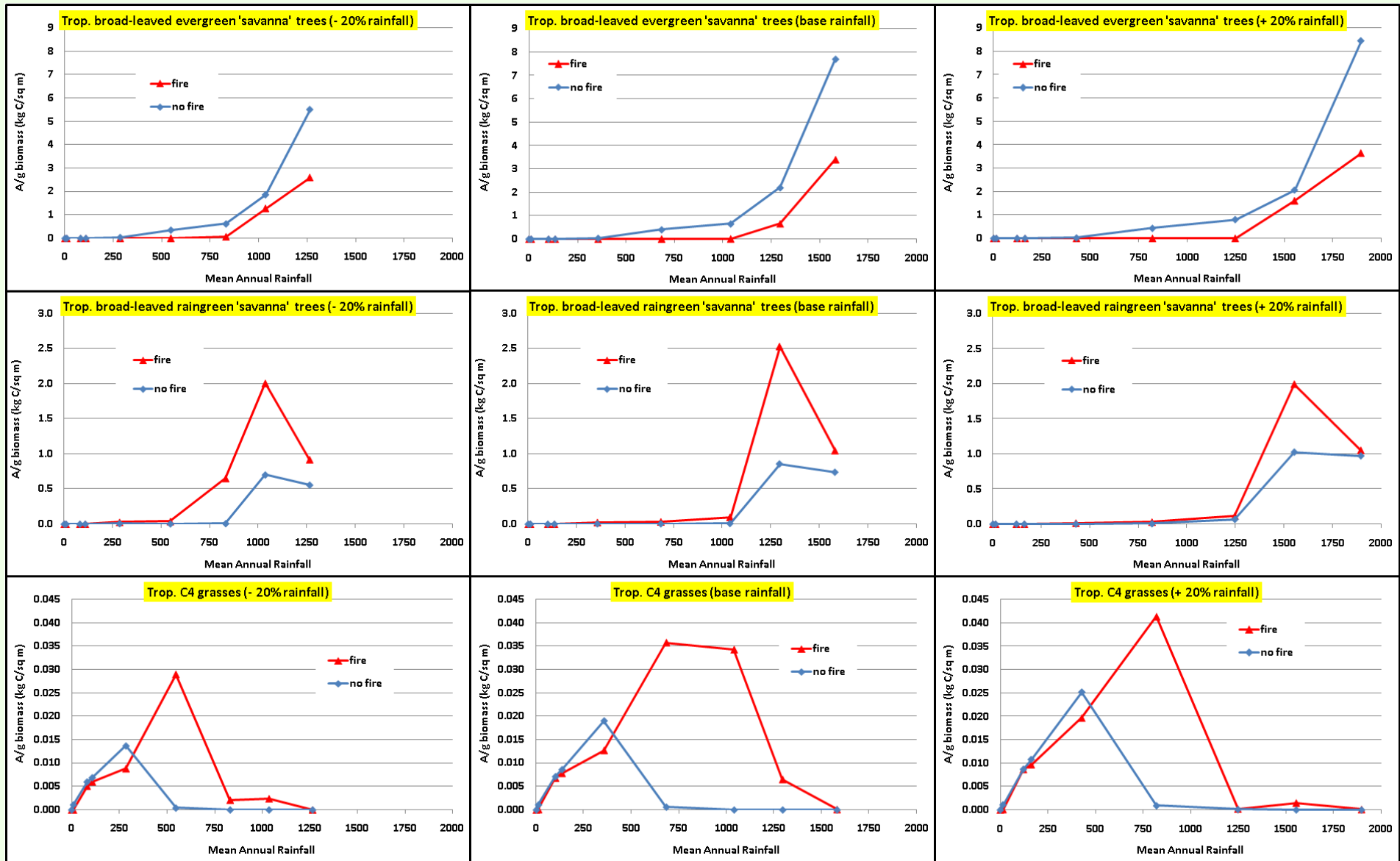
Soil C and N (uptake of N)

VOCs, methane, crops

ED/SPITFIRE

Mean Annual Rainfall gradient (high to low)





JULES: Joint UK Land Environment Simulator

New science:

Ecosystem demography and wildfire

Soil C and N (uptake of N)

VOCs, methane, crops

Land surface processes have taken more time

Testing ED/SPITFIRE in HadGEM3-A (atmosphere model)

Ocean ecosystems module is PlankTOM10

More sophisticated approach to ocean ecosystems than NPZD models

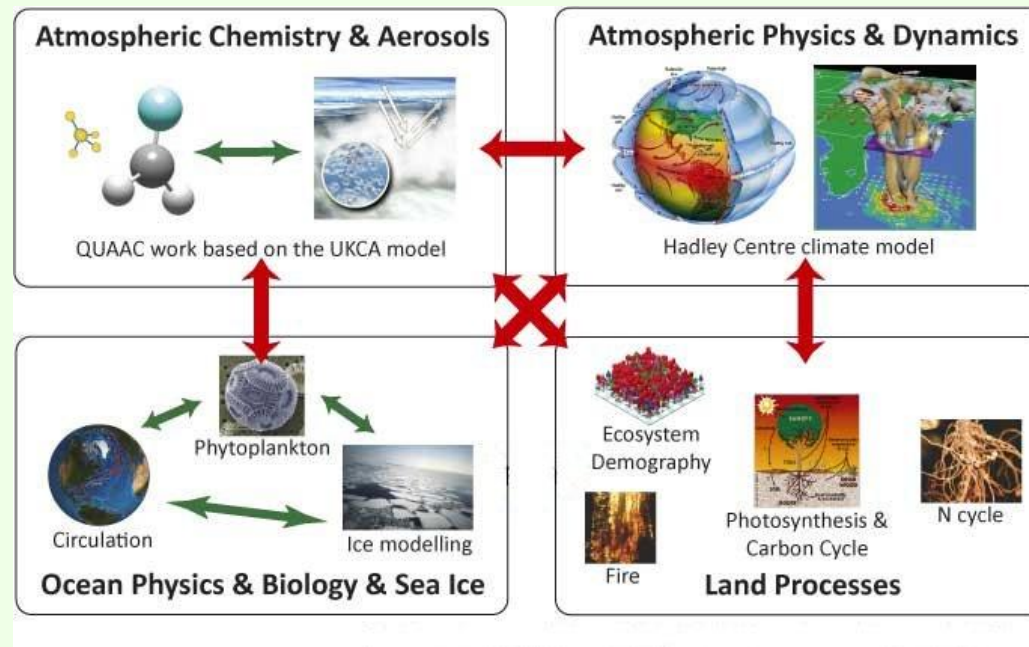
Ocean ecosystems module is PlankTOM10

More sophisticated approach to ocean ecosystems than NPZD models

Testing PlankTOM10 with HadGEM3-OA (atmosphere/ocean)

Soon testing PlankTOM10/HadGEM3-OA/UKCA-MODE

Of the four boxes shown, we're now testing three at a time in an interactive manner



We'll have QESM ready by the end of the year

Thank you for your attention

<http://www.quest-esm.ac.uk/>

Original ED developed and applied to an Amazonian forest by Moorcroft et al. (2001) *Ecological Monographs*.

So-called 'next' or 'Second Generation' Dynamic Vegetation Model.

ED is quite different from other Dynamic Global Vegetation Models (e.g. LPJ) and is based on the principles of 'gap' models → better at capturing within-gridbox heterogeneity in vegetation and fire fuel dynamics, and ultimately, ecological succession.

Global version produced by Rosie Fisher (formerly at Sheffield university, now at Los Alamos National Energy Laboratory), Allan Spessa and Doug Clark (CEH)

ED has 7 Plant Functional Types: C3 grass, C4 grass, Boreal Needleleaved Sumergreen (larch), Temperate Broadleaved Sumergreen (oaks, birch etc), Tropical Broadleaved Evergreen (rainforest), Tropical Broadleaved Deciduous (savanna trees), Temperate Needleleaved Evergreen (pine).

Not hard-wired → ED can flexibly incorporate more PFTs.

Concept of patches and cohorts- complicated!

QESM also incorporates SPITFIRE: effect of fires on mortality/emissions