Other Earth System Modelling activities

While QESM was being developed, QUEST scientists have used and developed other existing models.

- GENIE is a community grid-enabled modelling framework that runs very much faster than full climate models. It has very simplified representations of physical processes that has allowed for multi-millennial Earth system questions to be explored. It is also useful for research questions where regional climate patterns are not important.

- FAMOUS is a lower resolution Earth system model than QESM. It is a version of the previous Met Office Hadley Centre climate model, HadCM3, and runs ten times faster. It is therefore particularly useful for studies of climate change on glacial-interglacial timescales. QUEST invested in the development of a user-friendly community version of FAMOUS that includes land and marine carbon cycles, and sea-ice.

Publications

A full listing of QUEST research publications is constantly being updated by the QUEST synthesis team at the University of Bristol. Contact quest-info@bristol.ac.uk for more information.

Fisher, JB, et al (2010) Carbon cost of plant nitrogen acquisition: A mechanistic, globally applicable model of plant nitrogen uptake, retranslocation, and fixation. *Global Biogeochemical Cycles*. Vol 24, GB1014, 17 PP., doi:10.1029/2009GB003621

Huntingford, C, Fisher, RA, Mercado, L, Booth, B, Sitch, S, Harris, P et al. (2008) Towards quantifying uncertainty in predictions of Amazon 'dieback'. *Philosophical Transactions of the Royal Society* (B), 363, 1857–1864.

Ostle, NJ, Smith, P, Fisher, R, et al. (2009) Integrating plant-soil interactions into global carbon cycle models. *Journal of Ecology*. 97,5 851-863

Telford, PJ, Braesicke, P, Morgenstern, O and Pyle J (2009). Reassessment of causes of ozone column variability following the eruption of Mount Pinatubo using a nudged CCM. *Atmos. Chem. Phys*., 9, 4251-4260

Telford, PJ, Lathière, J, Abraham, NL, Archibald, AT, Braesicke, P, Johnson, CE, Morgenstern, O, O'Connor, FM, Pike, RC, Wild, O, Young, PJ, Beerling, DJ, Hewitt, CN, and Pyle, J (2010). Effects of climate-induced changes in isoprene emissions after the eruption of Mount Pinatubo. *Atmos. Chem. Phys.*, 10, 7117-7125, doi:10.5194/acp-10-7117-2010

Vogt, S, Vallina, M, Buitenhuis, ET, Bopp, L, Le Quéré, C (2010). Simulating dimethylsulphide seasonality with the dynamic green ocean model plankTOM5. *J. Geophys Res 5*. 115, C06021

QUEST Quantifying and Understanding the Earth System

NATURAL ENVIRONMENT RESEARCH COUNCIL

Creation of the QUEST Earth System Model

The QUEST Earth System Model is a new national capability

- The QUEST Earth System Model (QESM) enables interactions between the biosphere and climate to be investigated, providing decision-makers with insights into the effectiveness and consequences of climate policies.
- QESM is fully integrated with the Met Office Hadley Centre's family of climate models.
- It is an advanced tool that can examine Earth system feedbacks and processes for the Intergovernmental Panel on Climate Change (IPCC).
- QESM's development informs the NERC/Met Office Joint Weather & Climate Research Programme and NERC's Earth System Modelling Strategy.

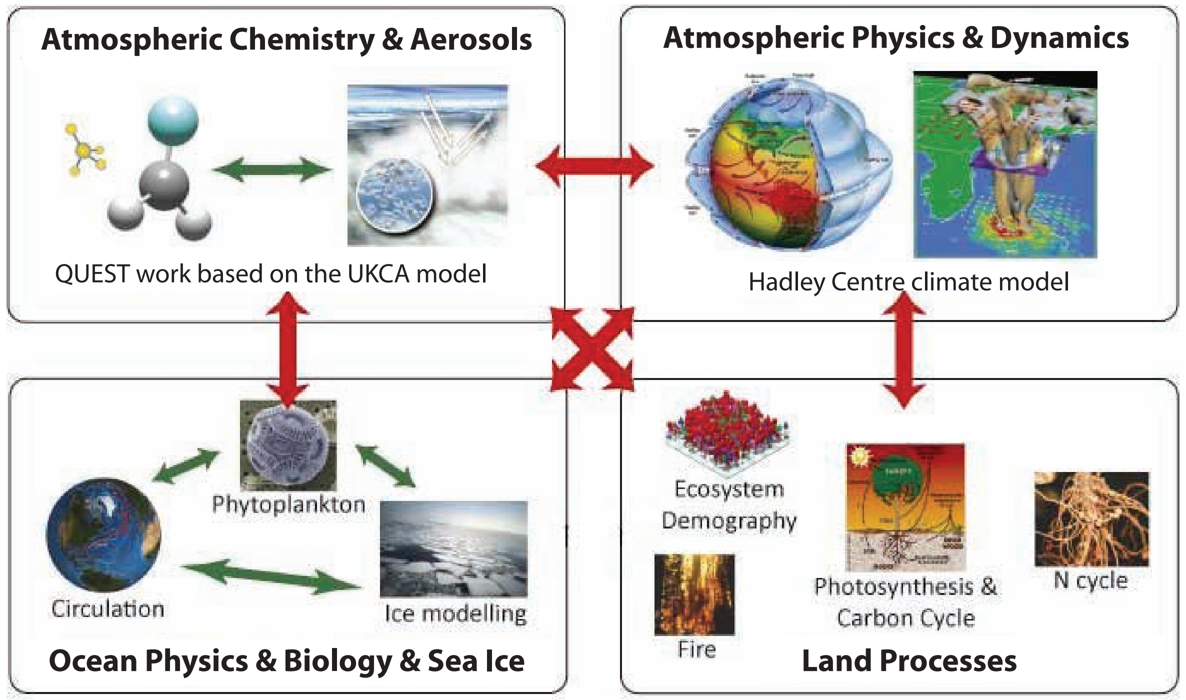
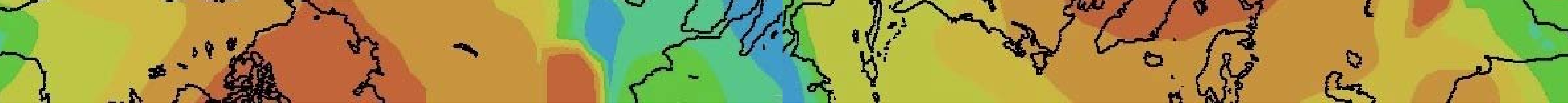


Figure 1: Summary of the four key components of the QUEST Earth System Model

QESM is a new Earth system model developed from the latest generation Met Office Hadley Centre climate model, putting it at the forefront of models being used for the IPCC. QESM includes new detailed representations of ocean, atmosphere and land processes. By coupling these elements directly within a physical climate system modelling framework, the interactions and feedbacks between climate, the biosphere and atmospheric chemistry can be explored. As a national capability, QESM offers the research community a valuable resource for investigating a wide range of Earth system processes and climate impacts.

Quantifying and Understanding the Earth System



- The development of QESM was technically highly ambitious. In physical climate models, atmosphere and ocean dynamics are coupled. To couple the new model components that represent living processes, many new interactions needed to be addressed (Figures 1 and 2).

- QESM runs at a lower resolution than the full Met Office Hadley Centre climate model, (HadGEM), which means it can include much more complex processes while making the same computational demand. The vision is that future Earth system models will include all these new processes at full resolution, as computer power increases. QUEST scientists have been involved in the development of the UK's strategy for Earth system modelling.

Ocean

- QUEST's new marine biogeochemistry model, QPFT, now includes 10 plankton functional types, allowing for more realistic representations of the processes involved in the cycles of the major elements nitrogen, phosphorus, silicon and iron. QUEST also pioneered an effective new approach to the remote sensing of plankton functional types to allow such a model to be directly tested. QPFT includes emissions to the atmosphere of nitrous oxide, a greenhouse gas, and dimethylsulfide, a compound involved in cloud formation processes. QUEST has also begun development of new modules for halocarbons and other climate-active marine gases. By incorporating the specific biogeochemical functions of marine organisms at a greater complexity than ever before, we can better understand their role in global climatic change.

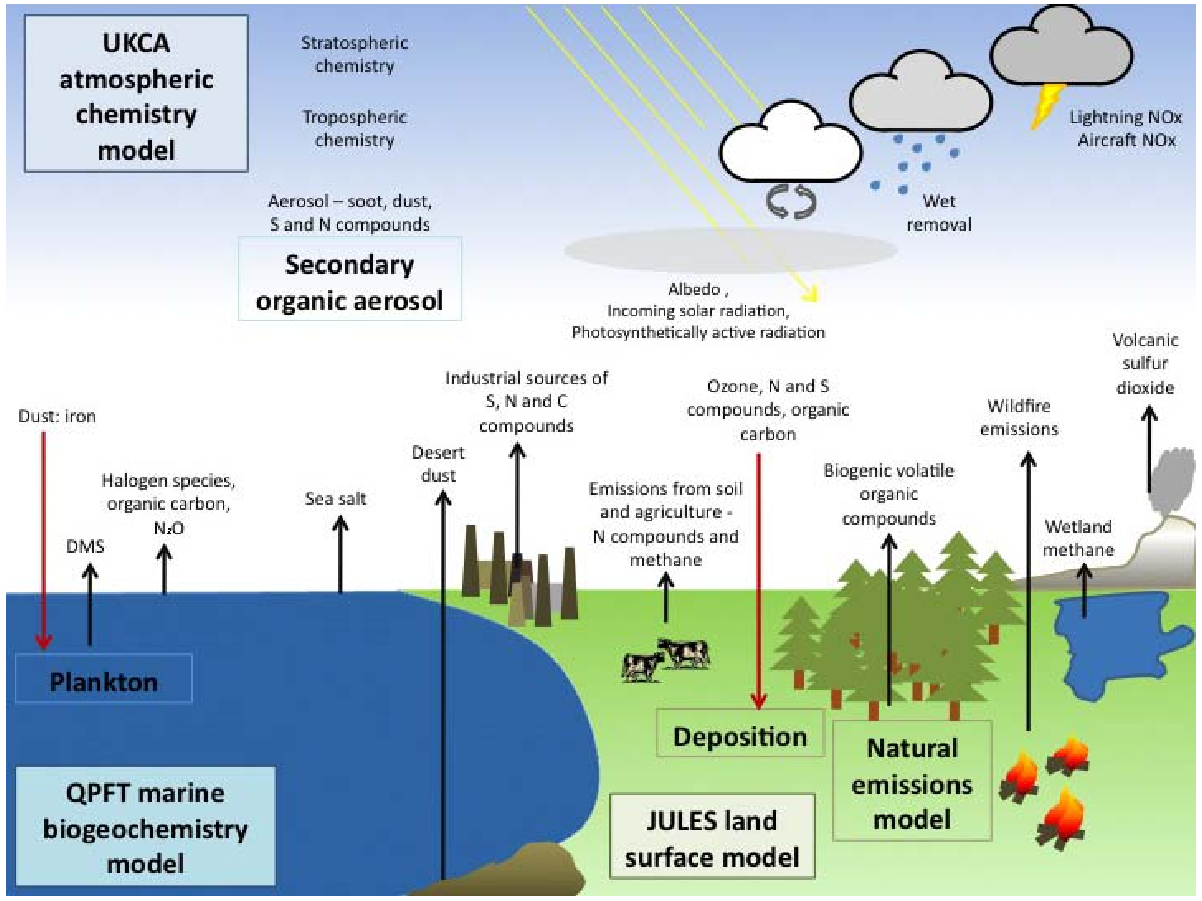


Figure 2: The interactions of the land surface model (JULES), the QPFT marine biogeochemistry model and the atmospheric chemistry and aerosols models (UKCA) used and developed for Earth system modelling by QUEST. Emissions of reactive chemicals from human and natural sources are a cause of air pollution, chemistry and influence atmospheric chemistry and climate.

Key: Volatile Organic Compounds (VOCs, such as isoprene), Dimethylsulfide (DMS).

Land

- Improved representation of vegetation dynamics and fire allows QESM to address more complex questions regarding ecosystem shifts and changes in carbon than many global models. The land module of QESM, JULES (the Joint UK Land Environment Simulator), now includes a statistical-dynamic description of vegetation dynamics (ED) involving new plant functional types, and a process-based fire model (SPITFIRE).

- An improved representation of the nitrogen cycle is being added through the ECOSSE soil model and a new "carbon-cost economics" model of carbon-nitrogen cycle interaction (FUN). Methane and crop models are currently also being embedded in JULES, through collaborations between QUEST and other projects. The model has been evaluated against vegetation trait data and satellite vegetation observations.

Atmosphere

- Atmospheric chemistry plays a fundamental role in climate and air quality. QESM uses the detailed atmospheric chemistry community model, UK Chemistry and Aerosol (UKCA). Developments of UKCA for QESM focused on the processes that control the sources, lifetime and distribution of organic aerosols and reactive greenhouse gases.

- QESM has a new reaction scheme for secondary organic aerosols, a radiatively important product of the chain of reactions that oxidize biogenic volatile organic compounds (BVOCs) emitted by vegetation and fires.

Testing QESM

The Mount Pinatubo eruption

- In terms of the processes that are represented and coupled, QESM is the most complete model in the UK and it is at the vanguard internationally. QUEST scientists used observational data from the 1991 Mount Pinatubo eruption to test an early version of the model and its components. When the volcano erupted, there were many chemical changes in the atmosphere, some of which caused the troposphere to be cooler and drier.

- These conditions caused global reductions in isoprene emissions from the biosphere, which in turn increased the atmosphere's oxidising capacity. This increased the atmospheric reactions that consume methane significantly, thereby reducing atmospheric methane by up to 5 Tg per year. The new processes included in the model allowed the interactions between the changing physical climate conditions, the biological sources of reactive molecules, and the resulting changes in greenhouse gases to be identified.

Pinatubo eruption; photo courtesy of USGS.

- In other studies using this "natural experiment", QUEST scientists investigated the way in which the eruption caused changes in important modes of climatic variability, such as the El Nino effect and the North Atlantic Oscillation.