The Role of Nitrogen

- N_2O is a long-lived greenhouse gas, whose emission appears to respond to temperature and may provide an additional positive climate feedback. A process-based model of the marine N_2O cycle has been embedded in QPFT, QUEST's ocean biogeochemistry model, to investigate how the production of N_2O responds to changes in atmospheric dust. Deposition of dust on the ocean surface provides a source of nutrients, such as iron, to upper ocean ecosystems. Changes in primary production in the surface ocean affect the chemistry of deep water and sediment, influencing marine N_2O formation and the ocean-to-atmosphere flux.

Photo: Dan/FreeDigitalPhotos.net

- The atmospheric deposition of anthropogenic reactive nitrogen also enhances marine productivity and ocean N_2O formation in regions downwind of high population continental zones. The impact of the additional atmospheric nitrogen deposition is especially marked in oceanic regions where upwelling of deep-water nitrate is lowest.
- The role of nitrogen in Earth's deep time has also been investigated by QUEST scientists. Early in Earth's geological history, the higher nitrogen concentrations in the atmosphere appear to have increased the greenhouse warming effect of methane and CO_2, offsetting the weaker radiative warming of a much fainter young Sun.

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.

Allen JI et al. (2010) Marine ecosystems models for Earth systems applications: the MarQUEST experience. *Journal of Marine Systems* 81 (1-2): 19-33. Pike R and Young P (2009) How plants can influence tropospheric chemistry: the role of isoprene emissions from the biosphere. *Weather* 64 (12): 332-336

Goldblatt C et al. (2009) Nitrogen-enhanced greenhouse warming on early Earth. *Nature Geoscience* 2 (12) http://dx.doi.org/10.1038/ngeo692

Maher BA, et al. (2010) Global connections between aeolian dust, climate and ocean biogeochemistry at the present day and at the last glacial maximum. *Earth-Science Reviews* 99 (1-2): 61-97.

Hirata J et al. (2008) An absorption model to determine phytoplankton size classes from satellite ocean colour. *Remote Sensing of Environment* 112: 3153–3159.

Maher BA, et al. (2010) Global connections between aeolian dust, climate and ocean biogeochemistry at the present day and at the last glacial maximum. *Earth-Science Reviews* 99 (1-2): 61-97.

Pike R, et al. (2009) CO_2 suppression, land use change, and anthropogenic forcing: Impacts on isoprene and the chemical composition of the troposphere. *Presentation at EGU* 2009, meetingorganizer.copernicus.org/EGU2009/EGU2009-5239.pdf.

Young PJ, Arneth A, Schurgers G, et al. (2009). The CO_2 inhibition of terrestrial isoprene emission significantly affects future ozone projections. *Atmospheric Chemistry and Physics*. 9, 8. 2793-2803

QUEST Quantifying and Understanding the Earth System

NATURAL ENVIRONMENT RESEARCH COUNCIL

Biogeochemical Feedbacks

Biogeochemical cycles link the flow of materials between the atmosphere, land and marine biosphere, and have important impacts on climate. When QUEST began, these relationships were poorly understood but work done within the programme has helped to tackle important questions on this topic. Do changes in vegetation and marine ecosystems have a positive or negative effect on warming? How do changes in nutrient supply affect ecosystems, the carbon cycle, and climate?

To address questions like these, QUEST has delivered new model representations of:

- Processes governing the formation and deposition of organic aerosols.
- The emissions of these molecules, particularly isoprene from land vegetation and dimethylsulfide and halocarbons from marine plankton.
- The sources, atmospheric transport, and transformations of ozone and dust.
- Representation of the biogeochemical roles of different plankton functional types within a new marine ecosystem model.
- Methane, an important greenhouse gas.
- Nitrogen cycling in marine and terrestrial ecosystems.

Highlights: Atmospheric Chemistry

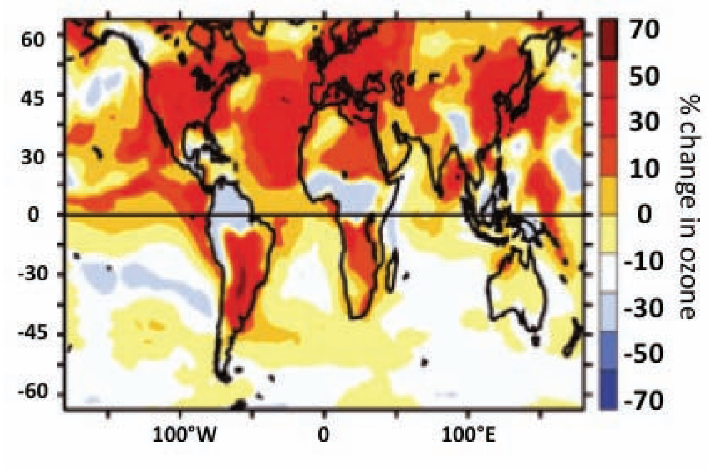
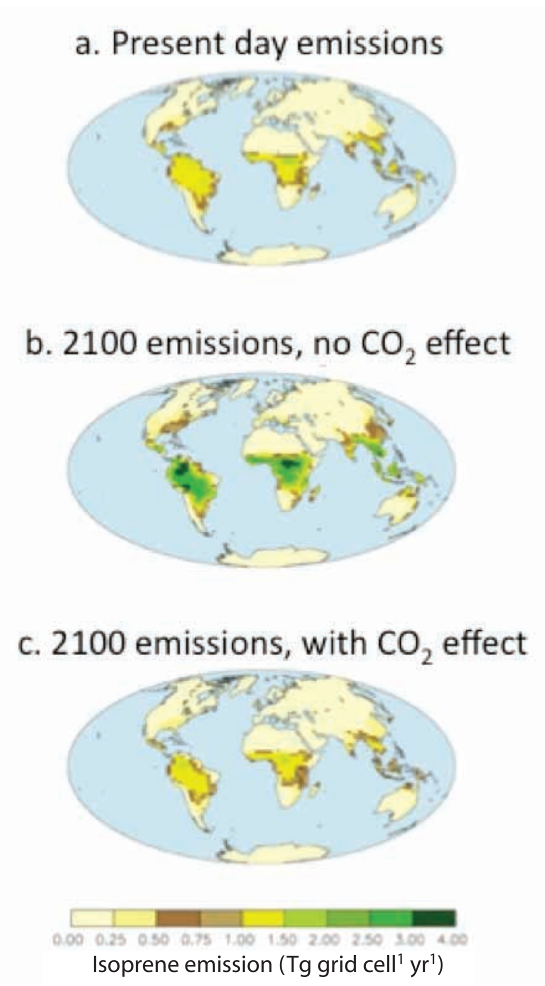


Figure 1: Change in the distribution of ozone when isoprene is included in model simulations for the month of July, current climate.
Image from Pike and Young (2009)

- Aerosols (small particles suspended in the air) play an important role in cloud formation, scattering of solar radiation, and atmospheric chemistry. Thanks to QUEST, important aerosol processes have been implemented in the UK Chemistry and Aerosols model (UKCA) and are now represented in dynamic Earth System Models. These include comprehensive biogenic emissions of reactive gases including isoprene, dimethylsulfide and fire-related emissions, and the subsequent formation of organic aerosols.
- Isoprene is a volatile organic compound emitted from plants, mainly in the tropics. It is involved in complex interactions with the powerful greenhouse gases ozone and methane, which influence climate. By including isoprene in Earth System Models, QUEST results indicate a dramatic alteration of the spatial distribution of surface ozone by as much as 50% in certain regions (Figure 1). It also extends the lifetime of methane in the atmosphere by more than 20%.

Quantifying and Understanding the Earth System

Figure 2. (right) (a) shows present day isoprene emissions; (b) shows the modelled increase in isoprene emissions as a result of predicted temperature rise (following the A2 SRES scenario). Figure (c) shows that if the fertilisation effect of rising CO_2 concentrations is taken into account, overall isoprene emissions are less than the present day. (Image from Young et al (2009)



- QUEST has also shown that higher temperatures increase global isoprene emissions, but rising atmospheric concentrations of carbon dioxide reduce it (Figure 2).

- QUEST has also estimated how converting land from rainforest, which emits high levels of isoprene, to croplands, which emit less, could affect global patterns of ozone near the surface (Figure 3). Crops grown in the tropics are more likely to be exposed to harmful levels of ozone in the warmer climate of 2100.

Dimethylsulfide (DMS)

- Dimethylsulfide (DMS) is a gas produced by some types of marine algae. It cools the Earth by altering cloud surface properties, making them more reflective. QUEST's marine biogeochemistry model, QPFT, explicitly represents the plankton that produce most of the available DMS, and their interaction with other organisms. This model has been implemented in QESM, where it will help quantify the climatic consequences of changing marine ecosystems.

- Researchers in QUEST have modelled the extent to which DMS emissions alter cloud properties. They found that the effects of DMS were strongest over the Southern Ocean in summer, which may help keep the ice shelves around Antarctica cool.

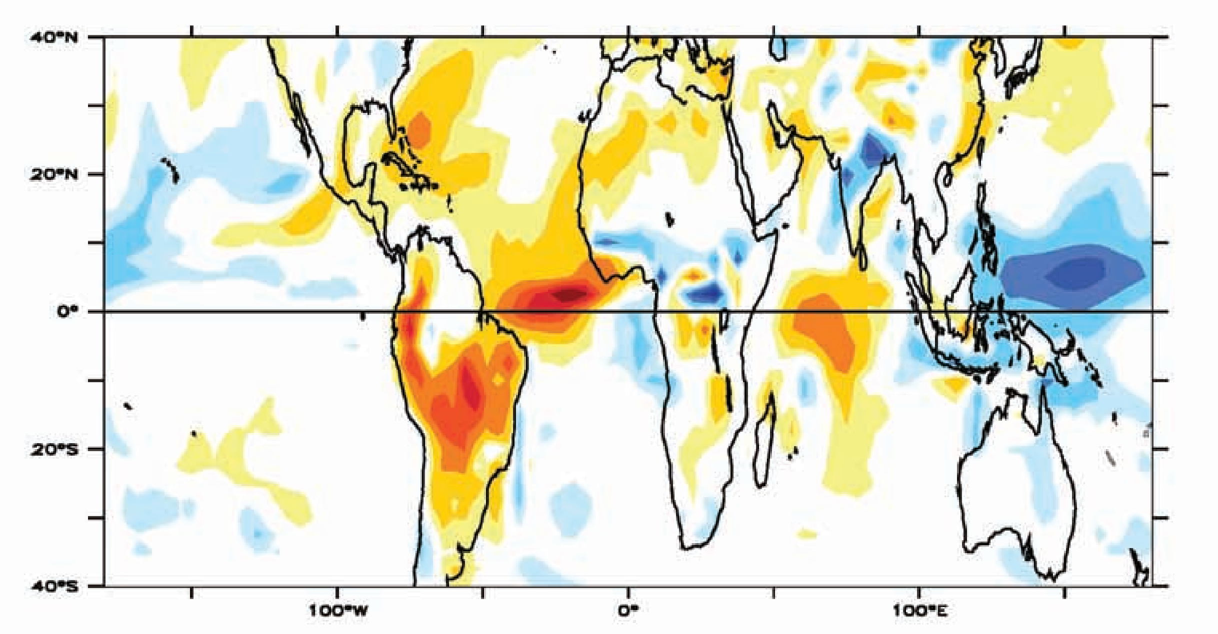


Figure 3: Change in surface ozone (ppbv) at 2100 due to a change in land use from forest to cropland. Image from Pike et al., (2009)

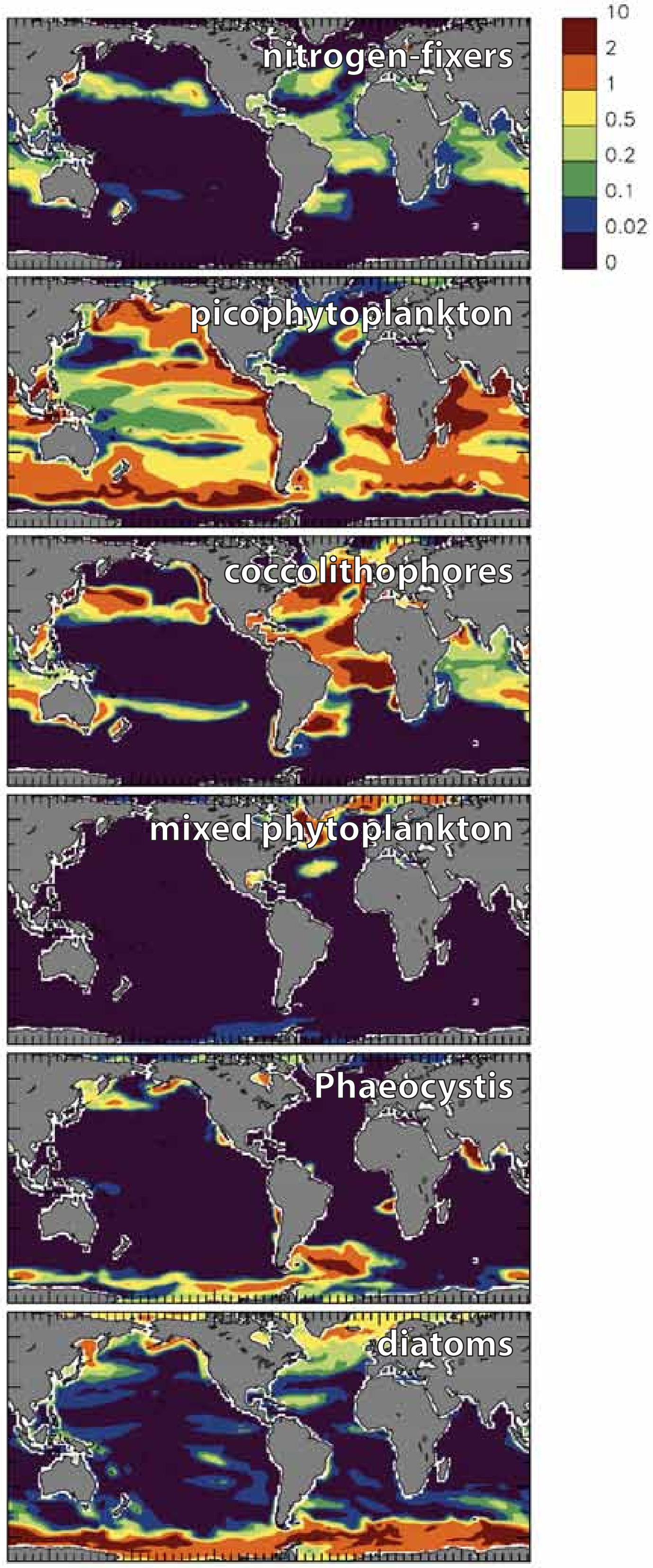


Figure 4: Surface concentrations (µmol/L) of the six phytoplankton types represented in the QPFT model. The plankton are in size order, from the smallest in the top panel to the largest in the bottom panel. The results are generally consistent with evidence of ecological niches for each of these phytoplankton. Image from C. LeQuéré.

Land Processes

- Remote sensing provides observations of Earth's entire surface, but satellite data products need to be translated into measures of key ecosystem processes. QUEST scientists developed algorithms that allow plankton functional types to be determined from space (Figure 4). This informs the development and validation of models that take biological complexity into account, and give a more robust representation of ecosystem response to global environmental change.

- QUEST has shown that in the past, rapid climate-driven changes in wetlands and peatlands are a likely major cause of the natural variation in atmospheric methane and CO_2 concentrations. Changes in the atmospheric chemical processes that consume methane cannot fully account for the low methane in ice ages.

- Dust links land-surface processes to radiative forcing, atmospheric chemistry, marine ecosystems and atmospheric CO_2 content, through processes such as iron fertilization. Large changes in atmospheric dust concentration between glacial and interglacial stages have been implicated in the natural cycle of changes in atmospheric CO_2 concentration. QUEST has taken an integrated approach to measuring and modelling dust and its climatic impacts for the present day and for the past. QUEST brought together international experts in the area of dust and climate change, spanning modelling, present day observation and remote sensing, palaeo-dust records, and biogeochemistry. They have updated modern and palaeo-dust flux data sets and have improved model simulation of dust properties, source regions, and dynamics.