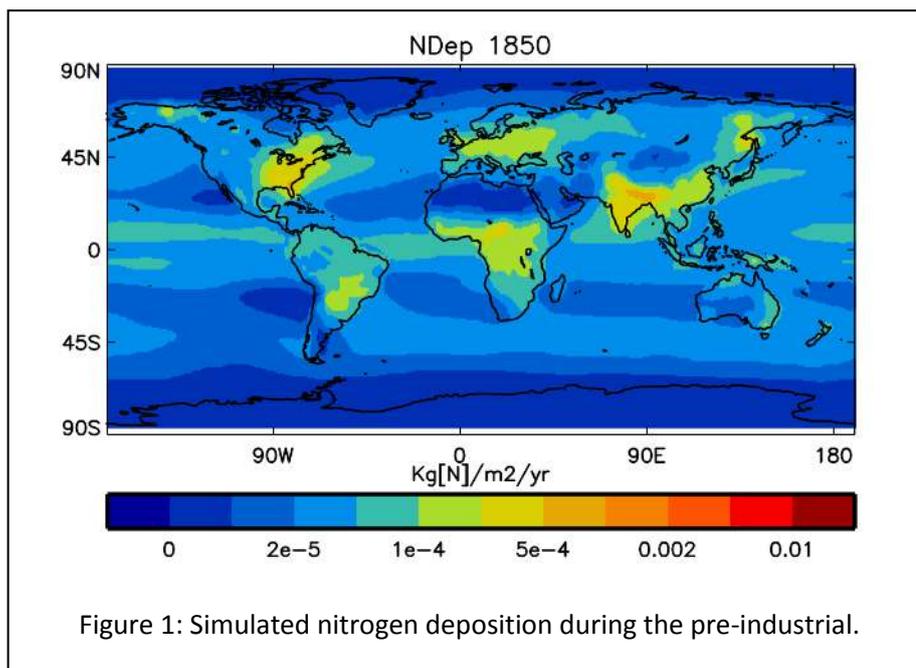


Nitrogen and the Terrestrial Carbon Cycle in UKESM1

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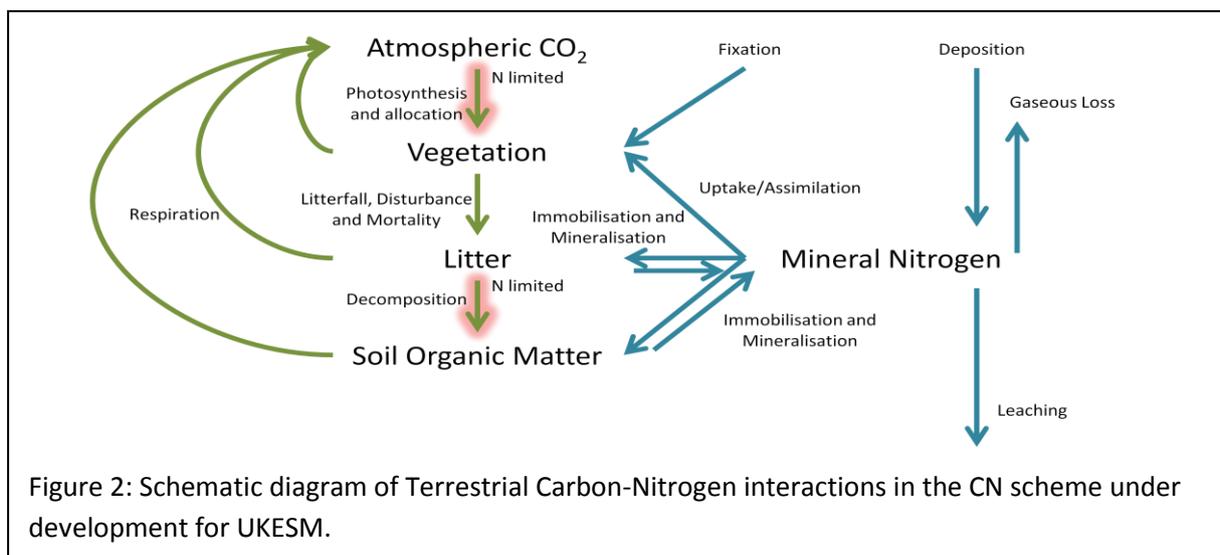
One key aspect of Earth System Models (ESM) that distinguishes them from their (physical) Global Climate Model (GCM) relations is the inclusion of interactive biogeochemical processes, such as the carbon cycle. The Earth's natural carbon cycle acts to moderate the amount of anthropogenic emitted CO₂ that remains in the atmosphere. Presently, approximately 50% of anthropogenic emissions remain in the atmosphere, with the other 50% taken up, in roughly equal proportions, by the land and ocean. The strength and performance of these carbon sinks is affected by climate change. Future changes in the efficiency of these sinks gives rise to so-called, carbon cycle feedbacks. An important additional phenomenon, generally not included in the current generation of ESMs, is the role nutrients play in plant productivity. Most current generation ESMs assume no nutrient limitation in their simulation of carbon cycle responses to increasing atmospheric CO₂ and a changing climate. To date only a few ESMs have included a nitrogen (N) cycle, the most important nutrient limiting terrestrial carbon uptake at the global scale. These models show a strong reduction in the future strength of the carbon sink associated with limited nutrient availability. A study by Zaehle et al. (2015) (<http://journals.ametsoc.org/doi/full/10.1175/JCLI-D-13-00776.1>) found most ESMs (excluding the 2 with N cycles) in CMIP5 likely underestimated the rise in atmospheric CO₂ over the 21st Century, under the RCP8.5 scenario, by between 29-147 ppm –that could potentially lead to a significant additional amount of warming.

The nitrogen cycle is highly perturbed in the modern world due to large scale use of fertilisers and other anthropogenic emissions. The availability of nitrogen to natural ecosystems is therefore partly determined by atmospheric deposition (Figure 1), as well as by direct N fixation from the atmosphere and that available in inorganic form. More nitrogen (fertiliser) in general means increased plant growth, higher vegetation carbon, higher litter production and therefore increased soil carbon. Limited N availability is likely to limit the benefits of CO₂ fertilisation on plant productivity. However, ecosystems can also redistribute their nitrogen, so for instance in a warmer



world more nitrogen may be mineralised from soils, leading to more nitrogen being available for vegetation. Plants (especially trees) are able to store carbon in a more nutrient efficient manner than soil. A warming world may therefore enhance vegetation carbon.

UKESM1 will include a representation of the terrestrial nitrogen cycle (outlined in Figure 2). The model links the carbon and nitrogen cycles to determine how much carbon can be stored under a changing climate under a given scenario of nitrogen availability. This is especially challenging as UKESM will include an updated version of the TRIFFID dynamic vegetation scheme, which allows vegetation to move and shift in response to climate change. The inclusion of a nitrogen cycle means that the simulated UKESM1 vegetation distribution will now respond to climate, CO₂ and nutrient availability. UKESM may therefore be unique in having both a nitrogen scheme and full dynamic vegetation amongst CMIP6 ESMs.



If you would like to know more, please contact Andy Wiltshire (andy.wiltshire@metoffice.gov.uk).