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Quantifying the impact of atmosphere-ecosystem interactions on atmospheric composition and climate in a fully coupled Earth system modelling framework.

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The composition of the atmosphere is the result of chemical compounds and particulate matter being emitted and removed at the surface and undergoing countless chemical reactions in the atmospheric environment. These chemical processes are mainly driven by solar radiation in the UV-visible spectral range. At the core of the chemical composition of the troposphere is ozone, a secondary atmospheric constituent, harmful pollutant and powerful greenhouse gas. Ozone is formed through photochemical reactions including nitrogen oxides and volatile organic compounds. The worldwide increase in tropospheric ozone concentrations since the beginning of the industrial revolution has resulted in air quality issues near the surface and a direct radiative forcing of around 350 to 400 mW/m2 contributing strongly to global climate change. Of great concern to national health services and policy makers are the harmful influence that air pollutants such as ozone and particulate matter exert on human beings and terrestrial ecosystems. The human health impact at present day is estimated at approximately 470,000 premature deaths due to ozone and over 2 million due to particulate matter annually. Similarly, an estimated $14 to $26 billion annual economic loss from ozone crop damage has been reported.

Precursors of atmospheric pollutants and radiatively active compounds are emitted from natural and man-made sources. While nitrogen oxides predominantly originate from human activity, many VOCs and primary organic aerosols have their origin in terrestrial vegetation. The world's ecosystems play a decisive role in the removal of important primary and secondary atmospheric trace gases and particles. Inversely, ozone and particulate matter greatly affect ecosystems with respect to their functioning and productivity. Ozone is known to reduce photosynthetic production and even damage or destroy plant tissue at the cellular level leading to significant economic losses. This might lead to an indirect ozone radiative forcing due to significantly reduced carbon assimilation rates which results in more CO_2 remaining in the atmosphere. In contrast to this, atmospheric particulate matter is able to shift the balance in solar irradiation to the diffuse fraction which has the potential to exert a substantial photosynthetic enhancement on the vegetation. This diffuse radiation fertilisation effect potentially counteracts the ozone impact on ecosystem productivity on the global scale.

In previous studies we have examined the individual effects of ozone and diffuse radiation on ecosystems, the global carbon cycle and climate via the indirect radiative forcing effects of ozone and aerosols. In this study we have expanded our investigation to the fully coupled Earth system applying the Met Office Hadley Centre flagship Earth system model HadGEM2-ES. We assess the combined and individual effects of tropospheric ozone and particulate matter on the world's ecosystems with this state-of-science model. We will outline the science and engineering behind the model and we will present first results from this innovative study that was executed in a partnership project of the Met Office with the University of Exeter.