The role of natural aerosol in biosphere-atmosphere interactions and feedbacks

Dr Alex Rap (SEE), Prof Dominick Spracklen (SEE)

Contact email: a.rap@leeds.ac.uk

This project will investigate the role of natural aerosol in vegetation-climate feedbacks, using state-of-the-art models to improve our understanding of biosphere-atmosphere interactions with important implications for future climate projections.

Background

Natural aerosols play an important role in vegetation-atmosphere-climate interactions (Carslaw et al, 2010). The terrestrial biosphere and the oceans are a large source of atmospheric aerosols, such as secondary organic aerosol (SOA), biomass burning from wildfires, dimethyl sulfide (DMS) from plankton, and sea-salt. Once in the atmosphere, these natural aerosols affect climate through their direct and indirect radiative effects (Rap et al, 2013). In addition, through their induced changes on diffuse surface radiation, these aerosol can strongly affect land vegetation growth. Plant photosynthesis is more efficient under diffuse radiation conditions, an effect known as diffuse radiation fertilisation which is essentially due to deeper canopy light penetration (Kanniah et al., 2012). Previous studies quantified the diffuse radiation fertilisation effect from biomass burning (Rap et al. 2015) and biogenic secondary organic aerosol (Figure 1; Rap et al., 2018), highlighting its large impact on the terrestrial carbon cycle.

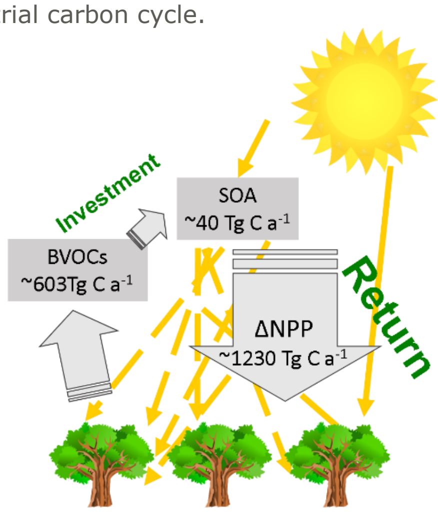

Figure 1: Global change in Net Primary Productivity (ΔNPP) caused by diffuse radiation fertilisation from Secondary Organic Aerosol (SOA) emissions. Globally, the forests get back more than twice as much benefit through the effect the increased diffuse light has on their photosynthesis.

In turn, the abundance and distribution of natural aerosol is controlled by changes in climate, e.g. biogenic aerosol emissions from land vegetation are strongly constrained by temperature, precipitation and radiation (Figure 2).

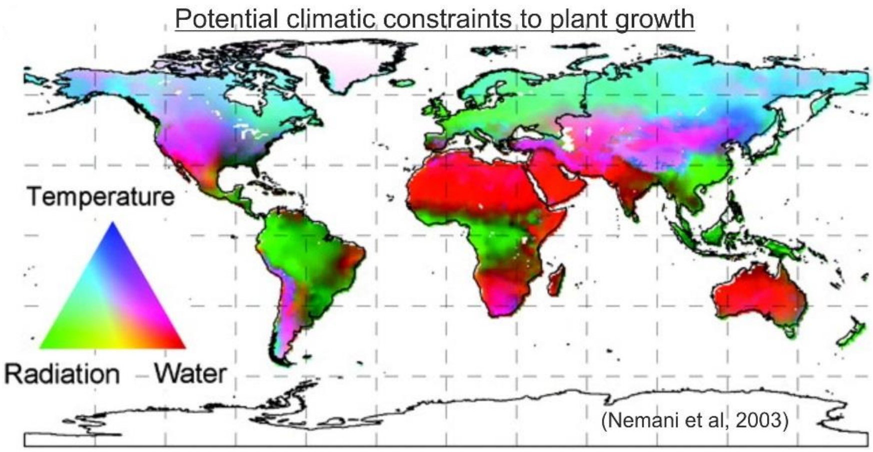

Figure 2: Distribution of climatic constraints to plant growth derived from long-term climate statistics.

While substantial progress has been made in recent years in this area, there are still many uncertainties in the current understanding of these complex interactions and feedbacks. In particular, the role of competing effects such as diffuse radiation fertilisation and temperature reduction, together with additional changes in soil moisture remains largely unexplored.

We now have at Leeds the ability to represent these interactions in a more comprehensive way than ever before. This project will therefore provide an exciting and unique opportunity to employ state-of-the-art global models to answer a series of key questions.

Objectives:

The overarching aim of this project is to analyse and quantify the role of natural aerosol in the various vegetation-atmosphere-climate feedback mechanisms. The approach will likely involve a combination of global aerosol, radiation and vegetation models, together with simulations using the new UK Earth System Model (UKESM).

While relatively flexible to allow for your interests, the studentship is likely to involve:

- A comprehensive assessment of regional and global natural aerosol emissions (with the associated uncertainties), both from process-based and from empirical models.
- Examining the role of natural aerosol in the observed NPP regional trends in recent decades.
- Exploring the extent to which anthropogenic aerosol and other pollutants (e.g. ozone) have affected the efficiency of these ecosystem feedbacks.
- Investigating the effect of temperature and atmospheric carbon dioxide changes on these interactions during the last few decades.
- Using future simulations to estimate how climate change is likely to affect these feedbacks.
- Assessing the role of these feedbacks in the terrestrial carbon cycle, testing the hypothesis that they are responsible for the budget imbalance in the global carbon budget.

Potential for high impact outcome

There are still large uncertainties in our understanding of how the terrestrial carbon cycle has changed in recent decades and how it is likely to evolve in the future. With access to cutting-edge techniques and support from our world leading research groups, this project will improve our understanding of biosphere-atmosphere interactions and feedbacks that may have important implications for future climate projections. This will likely be of interest to both the general public and to policy makers working in climate mitigation and forest conservation. It is expected that findings of this project will be published in high impact journals and will be presented at international conferences.

Training

The student will work under the supervision of Dr. Alex Rap and Prof. Dominick Spracklen and will be a member of two very active and supportive research groups in SEE, the Biosphere Processes Group and the Physical Climate Change Group. The project provides an exciting opportunity to exploit and to provide training in the brand new UK Earth System Model (UKESM). The student will also be part of the Leeds Ecosystem, Atmosphere and Forest (LEAF) research centre at the University of Leeds that brings together researchers from across the Campus. Through the high level specialist scientific training associated with this project, the student will develop a comprehensive understanding of vegetation-atmosphere interactions and will work with state-of-the art global land-surface and atmospheric composition-climate models. In addition, the student will learn how to communicate science and how to write high impact journal publications.

The successful PhD student will also have access to a broad spectrum of training workshops put on by the Faculty that includes an extensive range of training workshops in numerical modelling, through to managing your degree, to preparing for your viva. A full list of training opportunities is available here.

Partners

The student will collaborate closely with Dr Richard Ellis from the Centre for Ecology & Hydrology (CEH) Wallingford who will provide guidance and expertise on the land-surface component of the UKESM model.

Eligibility requirements:

A good first degree, Masters degree or equivalent in a quantitative science discipline (e.g. Physics, Mathematics, Chemistry, Environmental Science, Geography, Engineering) and a keen interest in global environmental problems. While a substantial part of this project involves computer modelling, prior experience is not essential - we provide high level specialist scientific training during the PhD.

References and further reading

- Arneth, A. et al.: Terrestrial biogeochemical feedbacks in the climate system, *Nature Geoscience*, 3, 525-532, 2010.
- Carslaw, K.S., Boucher, O., **Spracklen, D.V.** et al.: A review of natural aerosol interactions and feedbacks within the Earth system, *Atmos. Chem. Phys.*, 10, 1701-1737, 2010.
- Kanniah, K.D. et al.: Control of atmospheric particles on diffuse radiation and terrestrial plant productivity: A review, *Prog. Phys. Geog.*, 36, 209-237, 2012.
- Mahowald, N.: Aerosol Indirect Effect on Biogeochemical Cycles and Climate, *Science*, 334, 794-796, 2011.
- **Rap, A.**, Scott, C.E., **Spracklen, D.V.**, Bellouin, N., Forster, P.M., Carslaw, K.S., Schmidt, A., Mann, G.: Natural aerosol direct and indirect radiative effects, *Geophys. Res. Lett.*, 40, 3297-3301, 2013.
- **Rap, A.**, **Spracklen, D.V.**, Mercado, L., Reddington, C.L., Haywood, J.M., Ellis, R.J., Phillips, O.L., Artaxo, P., Bonal, D., Restrepo Coupe, N., Butt, N.: Fires increase Amazon forest productivity through increases in diffuse radiation, *Geophys. Res. Lett.*, 42, 4654-4662, 2015
- **Rap, A.**, Scott, C.E., Reddington, C.L., Mercado, L., Ellis, Garraway, S., Evans, M.J., Beerling, D.J., MacKenzie, A.R., Hewitt, C.N., **Spracklen, D.V.**: Enhanced global primary production by biogenic aerosol via diffuse radiation fertilisation, *Nature Geoscience*, 11(9), 640-644, 2018.