Trace gas emissions from Amazonia: impacts on atmospheric chemistry and climate

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Abstract

Biogenic trace gases influence tropospheric gas phase chemistry and atmospheric particle loadings. They therefore have effects both on air quality and on the radiation balance (and hence climate system) of the Earth. With NERC support (£566,000) we are part of a large international project – called the Cooperative LBA Atmospheric Regional Experiment CLAIRE project (part of the on-going Large-Scale Biosphere/Atmosphere Experiment in Amazonia). Within the framework of this project we wish to measure trace gas fluxes from the forest canopy and use the data to better understand the effects of greenhouse gases (GHGs) and volatile organic compounds (bVOCs) emitted from the forest on atmospheric composition and chemistry. This student will measure GHG fluxes, and will assist in the measurement of isoprene and monoterpene fluxes, from the forest canopy, and will use models to understand their effects in the atmosphere. The studentship is likely to be a CASE award with CEH Edinburgh, who will provide training, £1000 pa and substantial other support in kind.

Introduction.

Tropical forests are undergoing faster land-use change (e.g. by increasing cultivation of sugar cane, soya, oil palm and other crops) than any other region in the world. They are increasingly impacted by anthropogenic emissions and are forecast to respond strongly to changes in the coupled climate system. Tropical forests ecosystems interact with atmospheric composition, and hence climate, through cycling of carbon, water, and nitrogen. Carbon cycling includes direct cycling of CO_2 but also emissions of reduced carbon such as methane and biogenic volatile organic compounds (bVOCs). Phase transformations are also apparent within the carbon cycle: gaseous bVOC emissions give rise, on atmospheric oxidation, to biogenic secondary organic aerosol (bSOA), which has strong direct and indirect effects on climate. Thus a robust understanding and quantification of trace gas emissions, bSOA formation and biogeochemical cycling of macronutrients in the least polluted forest regions of the tropics is urgently needed as a baseline from which one can detect, quantify and forecast responses to future global change.

The study of these processes requires large integrated field campaigns to provide a full picture of the gas and aerosol phase characteristics and behaviour. The studentship proposed here will add to a major field campaign that will be held as part of the international Cooperative LBA Atmospheric Regional Experiment (CLAIRE) and for which we have secured NERC support (CLAIRE-UK). CLAIRE-UK will provide long-term measurements and models of the fluxes of reactive trace gases and particles within and above the forest canopy in the remote Amazon forest. This studentship will add long-term measurements of the fluxes of greenhouse gases: water vapour, CO_2, and CH_4.

The work will build on our recent success within our NERC-funded consortium project OP3, in which we applied similar approaches and methods to study 'Oxidant and Particle Photochemical Processes above a South East Asian Rainforest'.

The international CLAIRE project addresses five key research questions:

(1) which chemical and physical mechanisms control the oxidizing capacity of the atmosphere in the humid tropics and how will tropospheric chemistry respond to global change?

(2) Which gaseous species serve as precursors for aerosols in Amazonia and how are they transformed from the gas phase into the aerosol phase?

(3) What controls the climatically relevant properties of Amazonian aerosols at ambient conditions?

(4) What are the number and mass fractions of primary compared to secondary organic aerosols?

(5) How does forest ecology affect forest-atmosphere interactions?

Aims.

Within CLAIRE-UK, this studentship will focus on two specific areas arising from the overarching CLAIRE questions, in a coherent and self- contained project that will be mutually beneficial to CLAIRE(-UK):

1. To quantify above-canopy fluxes and within-canopy concentrations of greenhouse gases (GHGs), and
2. To link atmospheric composition in Amazonia to forest and climate drivers.

This studentship, as part of CLAIRE-UK, will provide unique insights into atmospheric composition in Amazonia both now and under plausible future land-use and climate change scenarios.

Methods.

Direct measurements of canopy-scale fluxes of GHGs and bVOCs will be made using the continuous flow disjunct eddy covariance technique (DEC), combining turbulence data from a sonic anemometer (at 50 m) with high temporal resolution GHG and bVOC measurements. GHG flux measurements will be the chief responsibility of the student and will be made using the Picarro G2301-m instrument to be procured by Rob MacKenzie as part of his start-up at Birmingham University (BU). The student will also assist in making bVOC flux measurements by proton transfer reaction mass spectrometer (PTR-MS). We aim to measure GHG and bVOC fluxes continuously for 12 months (January - December 2013) to give the first continuous 1-year time series of such fluxes from a tropical rainforest. A Brazilian collaborator, whom we will train as part of CLAIRE-UK, has already been identified. The data we obtain will allow for: (i) the compilation of a canopy C budget (combining our VOC and organic aerosol fluxes with CO_2 and CH_4 fluxes), (ii) comparison with MEGAN biogenic emission estimates and further optimisation of the light and temperature algorithms used in the model (with Alex Guenther, NCAR); (iii) pursuit of evidence of a seasonal shutdown of trace gas emission, thought to relate to leaf turn-over prior to the onset of the dry season; and (v) possible identification of the canopy-scale circadian control of emissions, as we have recently demonstrated for Malaysian ecosystems.

Training.

Specific training in trace gas flux and concentration measurements will be provided by our CLAIRE-UK partners, CEH Edinburgh, who are the UK's leading group for work of this kind. Disciplinary training in atmospheric chemistry and boundary layer dynamics will be provided by the supervisor, through attendance at Masters-level courses as necessary, and through attendance at summer schools such as that run at Arran every year by the National Centre for Atmospheric Science (NCAS). Rob MacKenzie and other members of GEES are closely involved in NCAS.

Standard GEES best practice for studentship training in generic and disciplinary skills will apply.

Selected References.

1. Hewitt, CN, … AR MacKenzie, et al., Ground-level ozone influenced by circadian control of isoprene emissions, Nature Geoscience, doi:10.1038/ngeo1271, 2011.
2. MacKenzie, A.R., et al., The atmospheric chemistry of trace gases and particulate matter emitted by different land uses in Borneo, Phil. Trans. Roy. Soc. Lond. B, 366, doi:10.1098/rstb.2011.0053, 2011.
3. Hewitt, C. N., Lee, J. D., MacKenzie, A. R., et al., Overview: oxidant and particle photochemical processes above a south-east Asian tropical rainforest (the OP3 project): introduction, rationale, location characteristics and tools, Atmos. Chem. Phys., 10, 169-199, 2010.
4. Hewitt, C.N., A.R. MacKenzie, et al., Nitrogen management is essential to prevent tropical oil palm plantations from causing ozone pollution, Proc. Natl. Acad. Sci., 106, 18447-18451, 2009
5. Pugh, TAM, AR MacKenzie, et al., Simulating atmospheric composition over a South-East Asian tropical rainforest: Performance of a chemistry box model, Atmos. Chem. Phys., 10, 279-298, 2010.