Understanding and predicting biogenic isoprene emissions at global scales

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Project summary Isoprene, a highly chemically reactive hydrocarbon emitted by terrestrial vegetation, plays important direct and indirect roles in (1) the production of tropospheric ozone, a pollutant and greenhouse gas comparable with methane, and (2) the formation of organic aerosol. Consequently, isoprene plays a significant role in climate. Available evidence suggests that the magnitude and geographic pattern of global isoprene emission rates will respond to future changes in CO$_2$ and climate. Emission rates per unit leaf area are highly sensitive to incident radiation, temperature, and CO$_2$, and vary by orders of magnitude among different plant functional types (e.g. grasses vs trees) and among species within a functional type (e.g. different species of deciduous tree), the spatial distributions of which are also expected to respond to change in climate. The only way to predict future changes in isoprene emission rates is to use bottom-up isoprene emission models, which scale up from sparse leaf-level and canopy flux observations to emissions at spatial scale of 10-100s km. Scaling up these sparse measurements relies on making assumptions about poorly understood physiological and biomechanical processes, e.g., the effect of leaf age and recent weather on emission rates. These assumptions result in large uncertainties in the magnitude and spatial distributions of isoprene emissions, compromising model predictions of future isoprene fluxes.

Estimates of regional isoprene emissions, inferred from satellite observations, are available for most of the globe at relatively fine temporal resolution (~100 km). Canopy-level isoprene emission data are also becoming increasingly available. Together, these data offer a potentially powerful way to test and improve bottom-up emission models, and associated model parameters. Significant discrepancies between emissions models and satellite data already identified are leading to better understanding of the underlying physical processes. However, to date, model improvement using the satellite data has been ad hoc. A better approach to model improvement is to use a Bayesian approach to formally estimate bottom-up emission model parameters using all the available leaf-level, canopy-scale, and space-borne data. The student will parameterize a suite of bottom-up isoprene emission models, and formally compare the predictive ability of each of these models using model selection criteria. The three key results will be: (1) a formal test of a variety of hypotheses about the processes governing isoprene emissions at regional to global scales; (2) one or more new parameterized isoprene emission models, which are consistent with all known data; (3) an estimate of uncertainty, in both model formulation and parameter values, which can be propagated through to isoprene emission estimates for the current climate, and for future climate scenarios.

Techniques The student will collate available isoprene emission data, and associated climatic data and data on the distribution of vegetation (e.g. distribution of plant functional types and species; satellite estimates of LAI). Given these data, the student will use a Bayesian analysis to parameterize and compare a suite of alternative bottom-up isoprene emission models. The student will:

1) Collate a large data set with which to improve understanding of biogenic isoprene emissions.
2) Identify a suite of candidate isoprene emission models.
3) Develop an existing parameter estimation scheme relating model predictions to the data.
4) Test key hypotheses about biogenic isoprene emissions, by comparing the predictive ability of the different models.
5) Use the model(s) to estimate the magnitude and uncertainty of current and future global isoprene emissions.

Training This project offers the candidate an excellent opportunity to gain experience in developing data-driven state-of-the-art models for use in Earth System models. The training includes:

1) The development of process-based models via the integration of ground-based, aircraft-based and space-borne data and knowledge about different biological processes.
2) The use of computational statistics to identify and parameterize optimal models.