



## Quantifying the impact of increased atmospheric CO<sub>2</sub> and climate change on photosynthesis using Solar Induced Fluorescence

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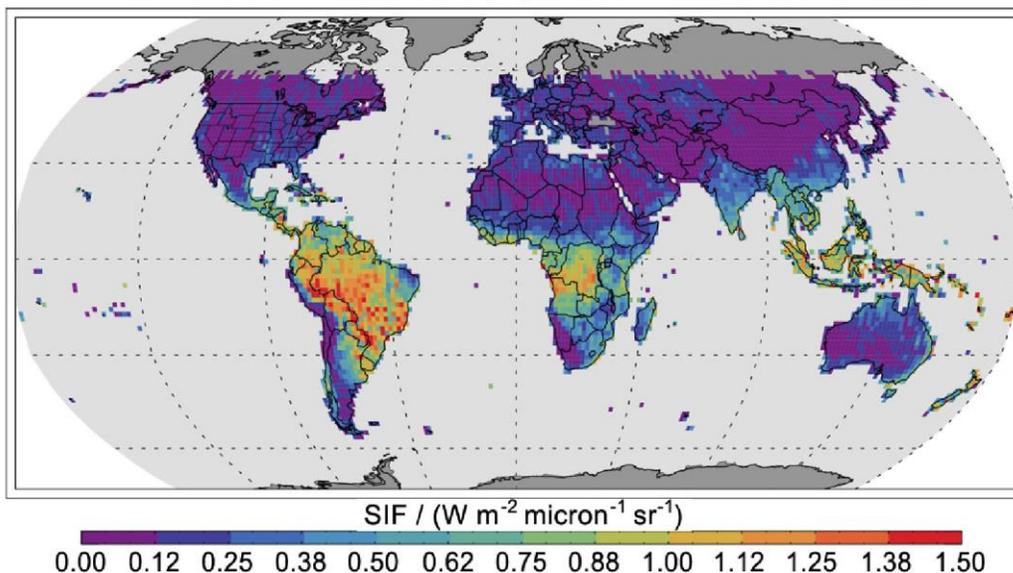
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Terrestrial ecosystems sequester around 25% of anthropogenic CO<sub>2</sub> emissions and continue to do so even as the concentration of CO<sub>2</sub> in the atmosphere rises. Despite our growing knowledge of the underlying processes the exact mechanisms for this remain unclear. Understanding whether or not this important sink of CO<sub>2</sub> will persist is vital: if it begins to weaken the growth rate of CO<sub>2</sub> in the atmosphere will increase, and hence the rate of climate change due to greenhouse gas forcing will also increase.

Photosynthesis is the principal mechanism by which carbon enters terrestrial ecosystems. At around 120 PgC/y it is the single largest flux in the global carbon budget. There is however a large uncertainty on this figure with published estimates having a range of around  $\pm 40\%$ . One key factor in this uncertainty is that direct observations of photosynthesis are difficult beyond the leaf scale, and global data sets tend to be based on (a) up-scaling of micro-meteorological measurements of net CO<sub>2</sub> flux which themselves do not directly measure photosynthesis and are limited in scale, or (b) remote sensing from instruments such as MODIS which measure the “greenness” of vegetation and relate this indirectly to photosynthesis. Ultimately, in both cases, it is relatively crude models which are used to go from the core observation to estimates of photosynthesis.

OCO-2 Solar-Induced Chlorophyll Fluorescence, Nov-Dec 2014



*Solar Induced Fluorescence as measured by NASA's OCO-2 mission. <https://svs.gsfc.nasa.gov/11788>*

Recently Solar Induced Fluorescence (SIF) has emerged as a direct measure of photosynthesis. SIF occurs during the processes of photosynthesis as a mechanism for disposing of excess energy to protect the photochemical apparatus of leaves. There is an established theoretical link between SIF and photosynthesis as well as strong empirical evidence that this works at the leaf scale and increasingly canopy to global scales. Critically it can be measured directly by several current satellites (e.g. NASA's OCO-2, see figure).

Consequently SIF provides an unprecedented opportunity to understand how photosynthesis is changing with changing CO<sub>2</sub> concentrations, and also to test Earth System Models (which are essentially climate models that represent a larger breadth of processes, such as the carbon cycle). Some existing research has examined relationships between satellite observed SIF and global modelled photosynthesis using simple relationships, but there is not yet an example of modelling SIF from first principles to make direct comparisons at the global scale.

This PhD project is based on the recent development of a canopy radiative transfer model that can scale from leaf level SIF to the canopy level and hence provides a tool that can directly predict SIF from Earth System Models. The project supervisors are also actively engaged in the retrieval of SIF from various satellite missions and fieldwork examining the response of SIF to elevated CO<sub>2</sub> concentrations at the UK's only Free Air CO<sub>2</sub> Enrichment (FACE) experiment at the Birmingham Institute of Forest Research (BiFoR), Birmingham, University.

The student on this project will:

- (1) Couple an existing leaf level model of SIF to the new canopy radiative transfer model.
- (2) Collate SIF data at both canopy and leaf scale from existing observation campaigns.
- (3) Use the model to predict SIF from the land surface component of UKESM, the new UK Climate Model.
- (4) Test UKESM based predictions of SIF against satellite observations of SIF.

The project will be the first time an end-to-end model of SIF (i.e. based on eco-physiological first principles and the physics of canopy radiative transfer) has been used at global scales and applied in an Earth System Modelling context. It is an exciting opportunity to work at the cutting edge of remote sensing technology and the development of a world leading Earth System Model.

**Training opportunities:**

The student will spend at least 3 months at NCEO Leicester with the CASE supervisor learning how SIF retrievals are performed from instruments such as NASA's OCO-2. This will help to deepen the student's knowledge of remote sensing techniques and widen their overall expertise. Visits will take place to the BiFor-FACE experiment to further understand the field data. The student will attend Flux Course 2019 in Colorado measuring and modelling carbon exchange between the terrestrial biosphere and the atmosphere. The PhD is directly affiliated with the National Centre for Earth Observation (NCEO). This brings with it a number of training opportunities, including the annual early career researcher meeting the annual science conference, both of which will expose the student to the range of activity in Earth Observation in the UK. In addition NCEO often provides bespoke training courses.

**Student profile:**

Applicants should have a strong background in either physics or plant eco-physiology and should be able to demonstrate experience of programming. They must be capable of working with a team of people with diverse expertise and be prepared to travel within the UK to collaborate with various teams at the Universities of Leicester, Birmingham and Reading and the UK Met Office.

<http://www.reading.ac.uk/nercdtp>