Can you provide an overview of the aims and objectives of your research?

In 2007 the Intergovernmental Panel on Climate Change (IPCC) reached a scientific consensus predicting that levels of global warming in the 21st Century are likely to be greatest over inland areas at high northern latitudes, whilst decreases in precipitation are likely to be greatest in inland areas in the terrestrial subtropical zone.

The aim of our research is to provide an empirical model that shows how such predicated climate changes may limit terrestrial CO₂ uptake in these global regions. To do this, the project analyses and synthesises real-world information taken from a large dataset provided by more than 100 research groups from around the world.

Can you describe what is meant by the net ecosystem exchange (NEE) of carbon dioxide and the variables that are considered in the research?

The net ecosystem exchange is the difference between the gross primary production (GPP) of CO₂ in the atmosphere and the total ecosystem respiration (TER). Therefore, the NEE can be understood as the total amount of CO₂ exchanged between the ecosystem and the atmosphere. Our research considers factors of variation that affect the GPP and TER, such as light (photosynthetic active radiation), soil moisture, vapour pressure deficit, and temperature.

How do you ensure continual and effective dialogue between the scientists and researchers involved in the collection of data on an international scale?

The dataset used in the research is called the Fluxnet Synthesis Dataset. The scientists who collect the data are committed to the principles of collaboration, communication, and co-authorship promoted in the data use policy. Whilst it has been a challenge to coordinate this on such a large scale, we believe that in order to understand how CO₂ flows between terrestrial ecosystems and the atmosphere cross biomes and continents, it is essential to conduct such research in a manner conducive to the effective transfer of data, information and knowledge.

What findings have emerged in the research so far that you believe will be submitted in the upcoming report to the IPCC?

Whilst predicted long-term changes in NEE may be different from predictions relating to regional and spatial variability of NEE, our results suggest that the most likely future climate change scenarios could strongly intensify terrestrial CO₂ uptake in high latitudes and weaken CO₂ uptake at low latitudes.

Has this project investigated all types of terrestrial ecosystems? What has each type revealed?

The present analysis is based on 559 site-years of eddy covariance data measured from 125 sites throughout the world from 1992-2008. The latitudes vary from 37 °S to 71 °N, longitudes are broadly covered, and elevation ranges from -2 m to 3,288 m. The climatic zones of the sites include polar tundra, maritime temperate, continental temperate, humid subtropical, Mediterranean, arid, semi-arid, tropical monsoon, and tropical wet-and-dry climates. The vegetation types include grassland, evergreen needle-leaf forest, deciduous broad-leaf forest, mixed forest, permanent wetland, open shrubland, closed shrubland, savannah, evergreen broad-leaf forest, and tundra. Stand age ranges from young seedlings to 500-year-old trees.

Which mechanisms most influence the relationship between climate, net CO₂ exchange, and atmospheric and biosphere processes?

The interesting discovery from this project is that the sensitivity of NEE to mean annual temperature broke down at a threshold value of 16 °C, above which terrestrial CO₂ fluxes were controlled by dryness rather than temperature. With global warming, the latitudinal belt with a mean annual temperature 16 °C would shift to the North. Thus, the dryness-control NEE area will become larger. Therefore, water availability can be said as the most influential factor in CO₂ transfer from the atmosphere to biosphere.

How do these climate models improve upon those already in existence?

We have found that NEE observed at eddy covariance sites is: (1) highly limited by mean annual temperature at mid- and high-latitudes; (2) highly limited by dryness at mid- and low-latitudes; and, (3) co-limited by both temperature and dryness around the mid-latitudinal belt (45 °N). This discovery furthers pre-existing knowledge on ecosystem CO₂ exchanges in modelling communities through the new understanding, discovered in our research, that the climate control parameters on terrestrial CO₂ exchanges vary in different climatic zones.
ONE OF THE most critical concerns within the scientific world, and the world at large, is that of the ecological wellbeing and sustainability of the planet. Over recent decades, research into global warming and climate change has become a major field of study for scientists aiming to learn more about the condition of the world’s atmosphere and environment. One of the major fears is that climate change may cause significant alteration to the world as we know it in a way that impacts organic life and human civilisation. Although dramatic climate changes have occurred throughout the history of the Earth, such changes have tended to occur over timeframes of hundreds of thousands or millions of years.

The last significant change in global temperature occurred around 10,000 years ago, since which Earth’s temperature has been notably stable, with a narrow band of only 1 °C of change. Almost all known human development has occurred in this period of temperate stability. Scientists predict that a rise in the Earth’s temperature of a further 2 °C would result in a catastrophic effect on biological life. Such a rise, however, may already have started in the atmosphere due to human activity, particularly over the past two centuries. Subsequently, scientists are on an important quest to expand upon existing knowledge about what causes and affects climate change in order to understand what lies ahead for the world we inhabit in the long-term on both a regional and global scale.

OBSERVING NET ECOSYSTEM EXCHANGE

One such study is led by Professor Chuixiang Yi of the School of Earth and Environmental Sciences at the City University of New York (CUNY). Yi and his team have been observing net ecosystem exchange (NEE) of carbon across biomes and continents, in efforts to understand how regional features, such as land, ocean, precipitation, and aridity, influence atmospheric CO₂ uptake levels.

The research hopes to obtain new knowledge about the climate-carbon cycle, which is of particular value given that imbalances in the NEE of CO₂ could accelerate (or decelerate) climate warming in the future. A fundamental feature of Yi’s research strategy stemmed from the identification that because NEE is the difference between photosynthesis and ecosystem respiration, variations in the climate of different global zones and biospheres may, in turn, affect NEE and global warming accordingly.

Consequently, Yi and his project members are seeking to produce a theoretical model drawn from large amounts of data submitted to the Fluxnet information database by scientists across six continents. For Yi, the hope is that the analysis and synthesis of data from these regions will help to establish long-term predictive insight into future NEE between the biosphere and the atmosphere, and in turn, the likely future scenarios of climatic change. The scientists involved in the project share data taken from micrometeorological instruments mounted on towers that measure the net exchange of CO₂, H₂O, heat, as well as the momentum between vegetation and atmosphere. The technique is called the eddy covariance method.

REGION SPECIFIC

The implementation of reanalysis of the eddy covariance data has resulted in some key discoveries for Yi and his colleagues. For example, levels of respiration (a factor centrally affecting overall CO₂ uptake) correlate with temperature, precipitation and substrate supply, and levels of NEE depend upon the climate-based limiting factors specific to a particular region.

Yi’s team has identified that at mid- and high-latitudes the amount of CO₂ that ecosystems take up from the atmosphere depends on mean annual temperature. Conversely, at lower latitudes, NEE appears to depend on aridity, particularly the dryness of the region. The research at CUNY suggests that expected climate change scenarios are likely to dramatically intensify terrestrial carbon dioxide uptake in high latitudes, whereas low latitudes will experience significantly reduced uptake.

Furthermore, the study has found that in zones where mean annual temperatures exceed approximately 16 °C, terrestrial CO₂ fluxes become dependent only on dryness. These findings demonstrate that approaches...
to control the sustainability of ecological climate change would be greatly enhanced by a methodology that considers the characteristics of different climatic zones, as opposed to wider universal control parameters.

NEW TOOLS

The investigation has also highlighted the value of the accurate and strategic analytical methods implemented in the project. Yi and his collaborators have developed a novel technique – the ‘perfect-deficit’ approach – assigns the best growth year at each site as ‘perfect’ and compares other years to it. A growth curve of the ecosystem over the best year is called the perfect curve, since it represents the greatest amount of plant growth that the ecosystem was capable of during the period of observation. “We can identify the impacts of climate extremes on these grassland ecosystems by comparing ecosystem performance in each year to the perfect curve,” Yi highlights. “The difference between the ‘perfect curve’ and the curve of any other year shows a deficit in plant growth and that deficit is highly correlated to extreme weathers, particularly to rainfall over the year.”

BENEFICIAL APPLICATIONS

One of the benefits of such research on a global and governmental scale is that it can help to improve environmental strategy and legislation through a better understanding of ecological carbon science. "This is crucial for the development of successful policy," explains Yi. “Management of the terrestrial carbon cycle will almost certainly be a key component of new policies requiring detailed understanding about the carbon balance of all major ecosystems. Our observational findings would provide much needed evidence for policymaker debates.”

This project has provided much needed pathways into the understanding of how climate change may serve to imbalance total net exchange of carbon, and, in turn, how such imbalance in net exchange of carbon may effect climate change and global warming. Such self-perpetuating systems of change observed within climate studies have led to particular concern amongst lead environmental scientists. Indeed, many scientists feel that the gravity of the problem is dangerously masked by the fact that the disturbance and damage being caused now will only become apparent in the future, when it may too late to reverse or adapt to the consequence of the changes. The axis of the problem with regard to human involvement is that this lag (of approximately 50-100 years) between the point in which the damage is caused and the actual consequence of the damage serves to confuse the degree of necessity and urgency within the very governmental policies required to affect a positive strategy of climate change control. The work of Yi and his partners marks an important step in confronting these issues and informing policies that could reverse this harmful trend.