Building an ecosystem-focused knowledge base

A Spanish-based novel research project is using satellite sensing to estimate vegetation parameters. **Drs Pilar Martin**, **Rosario González-Cascón**, **David Riaño** and **Arnaud Carrara** discuss how their work is delivering vital information to help improve understanding of global climate change trends




Can you describe the most relevant methodological components of Biospec?

PM: Biospec is organised around three multi-scale activities: data generation, model calibration and validation. We propose a scaling-up methodology which aims to properly link spectral information and biophysical parameters from small objects (leaves) to pixels and finally to composite scenes (vegetation canopies) using laboratory and field spectroscopy, airborne hyper-spectral images, and multi-spectral high and low resolution satellite data. In our study site, located in West Spain, we have compiled information from the leaf level (by measuring biophysical parameters plus spectral data in the field) to the canopy level (by acquiring airborne and satellite images with different spectral and spatial resolutions). The information is acquired simultaneously at the various spatial resolutions, which allows us to estimate the biophysical variables using information at different scales, compare the estimations across them and validate them using field data.

How important is field data to your research?

RG-C: All the field variables were measured with a constant and high frequency during two complete vegetative years (2009-11) at the main study site. This type of intensive field campaign is key because the dehesa (wooded pastureland) ecosystem is characterised by a dynamic herbaceous layer with an intense temporal variation pattern. These temporal changes along with the grass-tree interactions are strongly dependent on the yearly water availability. Therefore the robustness of the validation increases with the amplitude of the time period studied. To assure the reproducibility and quality of the measurements, detailed field, laboratory and data protocols were produced. We recorded a complete validated dataset collecting the spatial and temporal variation of field parameters – such as chlorophyll, nitrogen and carbon concentrations, water content and spectral data – of the two vegetation strata at leaf, canopy and ecosystem level. Laboratory calibrations of some variables such as leaf chlorophyll content along the whole vegetative period were carried out as basis for the validation at broader spatial scales. Nitrogen and carbon analyses were conducted in the Department of Environment from the Spanish National Institute for Agriculture and Food Research and Technology which has a broad experience in forest nutritional studies and has participated for more than 15 years in the Foliar Intercalibration Exercises of the ICP-Forests Monitoring Program.

What makes the study site at Las Majadas del Tietar in Spain such an ideal location for studying global trends?

AC: Firstly, the site meets the various technical criteria required to obtain good quality data. Flat topography and spatial homogeneity of the characteristics of the vegetation cover within an area of few km^2 guarantee both the quality of the surface-atmosphere fluxes measurements and the collection of a sufficient amount of remote sensing data representative of the studied ecosystem. Secondly, the micrometeorological flux station of Las Majadas is one of the oldest (operating since 2003) and probably the most comprehensive and complete (in terms of measured variables) that exists in Spain. Finally, the ecosystem studied is a managed and integrated agro-forestry system extends into the Iberian Peninsula. It thus impacts on the socioeconomics and biodiversity of the region. Since climate models predict greater changes (in both temperature and precipitation regime) for the Mediterranean area compared to global trends, such an ecosystem constitutes a potential hotspot for assessing impacts of climate change.

How do you use physically-based radiative transfer models to derive biophysical parameters from leaf- to ecosystem-level?

DR: Radiative transfer models explain how the light interacts with leaves, vegetation structure and soil background. The models simulate the spectral signatures of the leaf reflectance and transmittance or vegetation canopy reflectance, generally between 400 nm to 2,500 nm wavelengths. Biophysical parameters at the leaf level (such as chlorophyll, dry matter content, or equivalent water thickness) are model inputs, whereas to simulate canopy reflectance, variables such as Leaf Area Index (LAI), tree height, tree crown size or sun and sensor observation angles are also needed. An actual leaf or canopy spectra is measured with a field spectrometer, an airborne or a satellite sensor. The models are run for the widest range of possible known biophysical parameters. The simulated spectra that best matches the actual spectra serves to derive the biophysical properties, which is called model inversion. Since the number of possible solutions for the models can be very extensive, optimisation methods are generally required to derive biophysical variables for a whole airborne or satellite image.

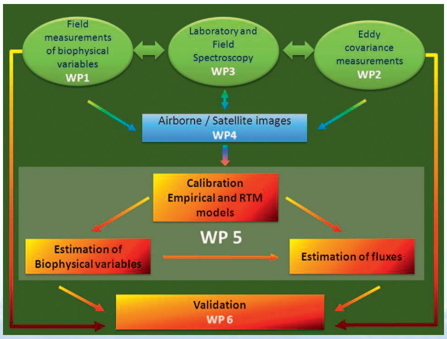
Redefining remote vegetation sensing

By combining fluxes measurements, fine-scale spectral observations and remote sensing products, a research collaboration called **Biospec** is aiming at developing tools which will robustly address water and carbon balances

SATELLITE SENSORS ARE well known for their potential to offer estimates of ecological parameters on the ground. The difficulty, however, is that most of these products are based on models that have been calibrated/validated over homogeneous ecosystems. For scientists working in the European Mediterranean this can present some major challenges, as the ecosystems found here are more complex. A project called Biospec is attempting to address this issue by contributing to the estimation of key vegetation biophysical parameters with the ultimate aim of improving our understanding of water and carbon fluxes by using a scaling-up methodology based on different types of remote sensing data. Biospec focuses on the analysis and quantification of the uncertainty associated with the estimation of the vegetation parameters at different spatial scales in complex Mediterranean ecosystems. One such example is the 'dehesa', which, Project Coordinator Dr Pilar Martin explains, is the dominant agroforestry system in Spain and probably the largest system of this type in Europe, making it a perfect location to study these very issues.

A COLLABORATIVE EFFORT

One of the key goals of Biospec is to help validate remote sensing products at different spatial scales. The intensive field campaign by the Biospec collaboration has allowed them to gather both optical and biophysical measurements of vegetation. Those measurements have been collected in Biospec's main study area, a FLUXNET site located at Las Majadas del Tietar in West Spain, where an eddy-covariance flux tower has been operating since 2003. Through this work, Biospec has been able to produce a consistent and well-documented in situ dataset which, when combined with the airborne and satellite data simultaneously acquired, can be used to properly validate remote sensing products in a typical Mediterranean ecosystem.



BIOSPEC PROJECT FLOWCHART

The Biospec research group is a multidisciplinary consortium of scientists experienced in environmental remote sensing applications and field measurement of vegetation biophysical variables as well as flux measurement and interpretation. The remote sensing group is made up of researchers from the Centre for Human and Social Sciences, part of the Spanish National Research Council, the Department of Geography at the University of Zaragoza and the Department of Geography at the University of Alcalá. These three groups offer a breadth of experience in environmental applications of remote sensing that is of much value to the project. In addition, participation of researchers from the Department of Environment based at the Spanish National Institute for Agriculture and Food Research and Technology and the Centre for Mediterranean Environmental Studies has been critical to the project's success. Martin points out that even though Biospec is considered to be a national research project, due to its funding, the team has placed much emphasis on the international links with experts from the U.S., Canada and Denmark working in similar fields who have collaborated on the project by providing their advice on specific research activities.

EMPLOYING THE MOST INNOVATIVE TECHNOLOGY

Recent technological advances have been used by the Biospec project group, as team member

MEASURING CHLOROPHYLL AND REFLECTANCE IN HOLM OAK LEAVES

David Riaño explains: "Within Biospec, we have validated the inversion of a canopy reflectance model (called PROSAIL) to estimate the vegetation canopy water content in our study site from different satellite sensors. We have generated a Landsat time series from 2009 to 2011 with which we can estimate vegetation water content and look into spatial and seasonal patterns in connection with evapo-transpiration and soil moisture measurements from the flux tower". The team has analysed MODIS data from 2009 to 2011 to generate a time series to look at weekly vegetation water content changes in relation with the flux tower measurements. Biospec has also provided an opportunity to estimate biophysical properties at leaf level, where they have measured leaf spectra and inverted the PROSPECT model to estimate changes in leaf water and chlorophyll content. A double beam hyperspectral sensor has recently been installed at the study site to obtain automated multi-angular continuous spectral measurements over the vegetation canopy. Such a system has been

designed by a research group from the Faculty of Forest Resources Management at University of British Columbia and is implemented in two FLUXNET sites in Canada, a coniferous forest and a mature Aspen stand. However, this is the first time that this type of multispectral multi-angular system operates on this type of heterogeneous Mediterranean land cover.

PRELIMINARY FINDINGS SIGNAL POSITIVE RESULTS

Active since January 2009, the project has made some significant progress and delivered important achievements. During the first two years a tremendous effort was put into data collection, both for field and airborne/satellite data. In this context, one of the project successes has been the design and standardisation of field protocols which allowed a complete and well-documented dataset for calibration and validation of the remote sensing products to be obtained. Martin comments that this field dataset includes biophysical variables (water, chlorophyll, nitrogen and carbon content, biomass and leaf area index) as well as spectral measurements (from visible to short wave infrared) of the two main vegetation strata (herbaceous layer and Holm oaks) and using this dataset, empirical models have been applied to the estimation of biophysical variables. "Preliminary results have shown consistent relationships between spectral indices and variables related with vegetation water and nitrogen content," she states.

Empirical models have also been applied to the estimation of the Holm oak leaf nitrogen content from hyperspectral data recorded in the field with an ASD spectroradiometer. Results have shown that temporal dimension is critical to establish a robust empirical relationship between leaf nitrogen content and optical measurements. The analysis of complete phenological years

EDDY CONVARIANCE TOWER, MAJADAS DEL TIETAR (SPAIN)

Remote sensing is the only tool with the potential to provide consistent information for the whole terrestrial globe at fine spatial scale

allows characterisation of optical response and biophysical variables behaviour, and achieving acceptable estimations when independent datasets are used. In agreement with other scientists, Martin says they have demonstrated that leaf nitrogen can be indirectly estimated through chlorophyll's optical response: "However, this research demonstrates that this approach may not be sufficient when temporal dimension is taken into account," she warns. "Further research that is needed includes the use of Radiative Transfer Models for the estimation of those vegetation parameters as well as the estimation of fluxes from remote sensing data." Preliminary results from the Biospec project have been presented at international conferences and several scientific papers are currently being prepared to bring the scientific community's attention to this work.

Over the past two decades the development of eddy-covariance networks has led to many new findings on the processes and drivers which govern the temporal patterns of carbon surface-atmosphere fluxes at an ecosystem scale. At the same time, atmospheric CO_2 concentration observations have been progressed to help quantify carbon fluxes at a global scale. Nevertheless, notes Biospec researcher Dr Arnaud Carrara, important uncertainties still remain on the spatial distribution of CO_2 fluxes at the surface of the globe, in particular at local and regional scales: "Remote sensing is the only tool with the potential to provide consistent information for the whole terrestrial globe at fine spatial scale. Therefore remote-sensing products hold the key to future integration of fluxes at local and regional scales". It is this that forms the basis of much of Biospec's work in the hope that by advancing remote sensing assessment of carbon exchanges, the framework for international environmental policies on climate change can also be improved.

INTELLIGENCE

Biospec

LINKING SPECTRAL INFORMATION AT DIFFERENT SPATIAL SCALES WITH BIOPHYSICAL PARAMETERS OF MEDITERRANEAN VEGETATION IN THE CONTEXT OF GLOBAL CHANGE

OBJECTIVES

To develop and improve remote sensing products for the estimation of biophysical parameters of Mediterranean vegetation in the context of global change.

PARTNERS

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