**European Cooperation in the field of Scientific and Technical Research - COST -**

**Brussels, 22 November 2013**

**COST 056/13**

**MEMORANDUM OF UNDERSTANDING**

Subject : Memorandum of Understanding for the implementation of a European Concerted Research Action designated as COST Action ES1309: Innovative optical Tools for proximal sensing of ecophysiological processes (OPTIMISE)

Delegations will find attached the Memorandum of Understanding for COST Action ES1309 as approved by the COST Committee of Senior Officials (CSO) at its 188th meeting on 14 November 2013.

**MEMORANDUM OF UNDERSTANDING**
**For the implementation of a European Concerted Research Action designated as**

**COST Action ES1309**
**INNOVATIVE OPTICAL TOOLS FOR PROXIMAL SENSING OF ECOPHYSIOLOGICAL PROCESSES (OPTIMISE)**

The Parties to this Memorandum of Understanding, declaring their common intention to participate in the concerted Action referred to above and described in the technical Annex to the Memorandum, have reached the following understanding:

1. The Action will be carried out in accordance with the provisions of document COST 4114/13 “COST Action Management” and document COST 4112/13 “Rules for Participation in and Implementation of COST Activities” , or in any new document amending or replacing them, the contents of which the Parties are fully aware of.

2. The main objective of the Action is to promote reflectance and fluorescence measurements of ecosystems for ground validation of models and satellite observations, using innovative spectrometers and UAV platforms, and develop a data sharing portal.

3. The economic dimension of the activities carried out under the Action has been estimated, on the basis of information available during the planning of the Action, at EUR 56 million in 2013 prices.

4. The Memorandum of Understanding will take effect on being accepted by at least five Parties.

5. The Memorandum of Understanding will remain in force for a period of 4 years, calculated from the date of the first meeting of the Management Committee, unless the duration of the Action is modified according to the provisions of section *2. Changes to a COST Action* in the document COST 4114/13.

## A. ABSTRACT AND KEYWORDS

Important European and international initiatives (SPECNET, BIOSPEC and COST Action ES0903) explored the use of proximal optical sensing of ecosystems where carbon and water vapor flux are estimated by eddy covariance techniques. Such optical observations provide data at the high spectral, temporal and spatial resolutions necessary to more fully comprehend the links between light use, plant physiology and ecosystem functioning and provide key validation datasets for satellite remote sensing missions such as tSentinel and the proposed FLuorescence EXplorer (FLEX) candidate missions.

The recent advances in UAV platforms and optical sensors provide unprecedented opportunities for high spatial, spectral and multi-angular near-ground Earth observations. This will enable scientists to answer ecological and physiological questions at multiple scales through integrated empirical and modeling methods. Important progress is also being made in remote sensing of steady-state fluorescence, the most direct proxy for photosynthesis. The FLEX candidate mission, selected for further studies, will also benefit as this Action will support FLEX validation and calibrations campaigns. Furthermore, scientists have recognized the need to develop a 'smart' on-line platform to process and analyses optical data along with biophysical and water/carbon flux measurements and share these with other scientific communities and stakeholders. This will also be addressed in this Action.

**Keywords**: reflectance, fluorescence, hyperspectral sensors, Unmanned Aerial Vehicles, ecosystem observations, model data integration

## B. BACKGROUND

### B.1 General background

The importance of understanding biogeochemical cycling in terrestrial ecosystems under increased climatic variability and the impacts of extreme climatic events are of highest scientific and socio-economic importance. However, the use of optical observations from satellite platforms, providing global coverage, and ground sample measurements, providing local detail, to understand these issues has not yet been optimised, due to the lack of suitable near-ground observation platforms. Consequently, little work has been done to investigate the 'scaling' issue linking data streams with heterogeneous spatial and temporal resolutions. This issue plays a key role in comparing proximal spectral measurements with observations from satellite platforms for validation purposes. Neither has much work been done to investigate the relationship between vegetation reflectance and fluorescence (the closest measurement to the actual dynamics of photosynthesis). It is the aim of this Action to more fully investigate these issues by exploiting existing research site networks (e.g. ICOS) and investigating newly developed spectral measurement systems mounted on Unmanned Aerial Vehicles (UAV) to make observations at multiple spatial scales and view angles and establish links between proximal optical measurements and observations from satellite platforms. This integrated infrastructure and measurement approach will not only enhance use of current Earth observations but it also offer opportunities for the validation and calibration of new satellite missions. There is also a need to make these data, and products derived from, them more readily available to the scientific and wider communities through use of an automated and 'smart' on-line data storage and retrieval platform.

This Action will build on previous Actions (ES0903 "EUROSPEC", ES0804 "ABBA", and ES0802) to address these issues and provide a support network (with meetings, Short Term Scientific Missions (STSMs), TraningSchools for Early Stage Researchers (ESRs) and co-ordinated field campaigns) for carbon and water vapor flux research (e.g. ICOS and FluxNet) and space missions (e.g. Sentinels, EnMap and FLEX).

**B.2 Current state of knowledge**

In order to advance knowledge of biogeochemical cycling in a changing climate and to understand the consequences, a deeper insight into processes that regulate carbon and water exchanges between terrestrial ecosystems and the atmosphere is required, and local long-term proximal measurements and global Earth observations are key to making progress (Gamon et al, 2010). Ecosystem carbon and water fluxes are measured by methods which operate at different spatial scales, such as eddy covariance (EC) techniques (Valentini et al., 2000; Baldocchi et al., 2001) and aircraft and satellite remote sensing (RS) measurements (Hunt et al., 2003). Nevertheless, the importance of being able to effectively fuse information from this range of scales (local sample to regional or global scales) has been highlighted as necessary (Conant and Paustian, 2002), although not yet achieved. Linking EC measured ecosystem fluxes and remotely sensed information is one of the most promising methods for scaling up surface fluxes (Gitelson et al., 2004; Grace et al, 2007; Gamon et al, 2010). Furthermore, significant further effort is required to link biophysical variables and water and carbon fluxes to spectral measurements from proximal sensing and relate these airborne and satellite observations.

This Action will make significant steps beyond single site studies by combining world class expertise in proximal optical sampling and newly available near-ground platforms (UAVs) within the current network of flux towers. In doing so, Europe will be at the forefront of improving the linkages between ground and space based measurements of carbon sequestration and water vapor flux in terrestrial ecosystems.

**B.3 Reasons for the Action**

Through the ES0903 COST Action, a new optical sensor systems suitable for deployment at flux sites and on UAVs has been developed. However, the development of measurement techniques in the spatial domain are still required. Furthermore, the European Space Agency (ESA) has recently listed remote measurements of fluorescence from aircraft, with a view to supporting the proposed European Space Agency (ESA) FLEX satellite mission (currently in Phase A/B1 (http://www.esa.int/esaCP/SEMD9AGMTGG_index_0.html)), as a high priority and is encouraging the development of proximal sensing and airborne and satellite fluorescence measurements. This Action will address both of these needs.

The main aims of this Action are to resolve the following questions:

i) How can calibrated and validated spectral data be collected, processed, quality assured and shared across different scientific communities (satellite RS, field proximal observation, and water and carbon flux measurement communities)?

One of the keys to success of optical sampling strategies focusing beyond a single research site is the availability of an on-line platform to collect, process, visualize, and share proximal sensing data and products and make them available to the wider community. The SPECCHIO database (www.specchio.ch/) (Hueni, Nieke et al. 2009; Hueni, Chisholm et al. 2012), offers a promising approach. However, although the system is very flexible, regarding storing information, more discussion is needed within the community to standardize formats and metadata and develop the 'smart' integration of ecophysiological, biophysical and optical data (e.g. automated upload of data, assignment of quality flags, uncertainty estimates, and production of standard data products) and do so in a transparent manner. A wireless communication dataflow from remote sensors on flux towers and UAVs into an on-line 'smart' generally accessible database with associated data produces has not yet been developed. This Action will use existing and new algorithms, technologies and wireless communication protocols to implement such a system based on the SPECCHIO database. In addition, this Action will contribute to the definition of metadata standards required to describe optical datasets linked to biophysical and ecophysiological measurements.

ii) What is the potential for upscaling ecosystem observations from optical sensors on UAV platforms by means of model and data integration?

The extraordinary advance in UAV technology has opened new opportunities for ecology studies: micro-hyperspectral sensors can now be mounted on UAVs and programmed to acquire data in the spatial domain using statistical robust sampling approaches, retrieve directional reflectance of 'challenging' targets, such as forest canopies, and do so in non-intrusive ways, minimizing damage to Earth surfaces or interfering with other measurement systems. The integration of such an approach with Earth observation data by means of model/data fusion offers significant opportunities to answer scientific questions from leaf to regional scales and provide information in temporal and spatial domains not possible to investigate previously. Furthermore, the spatial information acquired by the UAVs will enable the surfaces contributing to integrated EC flux measurements (not previously quantifiable (Moncreiff et al., 1995)) to be assessed through development of two-dimensional footprint models. It may then be possible to model hyperspectral reflectance in conjunction with the exchange of carbon and water vapor and couple these to spatially explicate footprint models to create a “footprint simulator”, enabling the integration of EC flux and observations from UAVs and satellite platforms.

iii) How can reflectance and fluorescence information be integrated to investigate mechanisms regulating light use efficiency and build ground validation networks for Earth system models?

Recent research has dramatically expanded our ability to monitor vegetation photosynthesis with remote sensing, allowing us to track plant growth and stress responses over various temporal and spatial scales. However, an accurate quantitative estimate of photosynthetic rate from RS remains elusive, in part because of the difficulty in knowing light use efficiency. This “conversion efficiency” can be assessed several ways, some of which involve assessing the distribution of energy once it is absorbed by leaves and canopies via fluorescence or reflectance. The ESA has recently listed the remote measurement of fluorescence (from aircraft, with a view to supporting the proposed FLEX mission) as a high priority and is encouraging network activities on the development of ground, airborne and satellite fluorescence measurements. FLEX will be the first mission explicitly designed to monitor the actual vegetation photosynthesis, fundamentally new information from space observations. In this context, the regional up-scaling of detailed point measurements at EC towers, and the local but spatially distributed measurements from UAVs, will enable spatial analysis and the correlation between plant physiological performances and stress factors to be addressed, providing useful forcing for existing global climate models through the link between carbon and water fluxes. Although fluorescence measurements are unique and promising, they have also been sometimes viewed with scepticism as there is little experience of interpretation.

Recently, the first global maps of terrestrial fluorescence have been produced, using the high spectral resolution interferometer aboard the Japanese Greenhouse gases Observing SATellite (GOSAT) (Joiner et al., 2012; Frankenberg et al., 2011; Guanter et al., 2012), and this shows fluorescence to be related to global maps of gross primary production (GPP). However a validation of these relationships is not possible as direct GPP measurements at the spatial resolution of the current satellite measurements do not exist. Thus, there is a strong need to conduct such validation on a smaller scale, typically at EC sites by means of tower and field measurements with UAVs. Moreover, there is a need to better understand the fundamental processes involved in the dynamical changes of fluorescence, for which measurements with high temporal resolution resolving the diurnal cycle and the seasonal dynamics are definitely needed. This Action will contribute to the interpretation of the global fluorescence maps compiling a list of existing sites equipped for fluorescence and productivity measurements and making recommendations for the development of a ground validation network.

### B.4 Complementarity with other research programmes

This Action will be linked to the following networking, research, and infrastructural projects: i) Integrated Carbon Observation System (ICOS): the Action will support the implementation of reflectance and fluorescence measurements at ICOS sites; ii) SPECNET, FLUXNET and COST Action 2100 (ICT): This Action will enhance the collaboration with international proximal RS, optical Earth observation and flux measurements experts and the use of wireless communications within these networks; iii) European Facility for Airborne Research (EUFAR): This Action will integrate proximal sensing observations from UAV and aircraft observations; iv) ICOS-INWIRE: this Action will help enhance the capabilities of the ICOS infrastructure to further meet the needs of operational users in the GMES Atmosphere and Land Core Service Elements.
Researchers involved in these networks have already expressed an interest in participating in this Action and organizing joint activities.

## C. OBJECTIVES AND BENEFITS

### C.1 Aim

The aim of the Action is to promote reflectance and fluorescence measurements of ecosystems as ground validation networks for Earth system models and global satellite observations, using innovative spectrometer and UAV platforms, and develop automated wireless communication systems with on-line spectral information storage, quality assurance and data product sharing portals.

## C.2 Objectives

The objectives of the Action are: i) to support the ICOS network, bringing together EC scientists and the proximal sensing community, in order to enhance and enlarge the global spectral sampling network; ii) to harmonize instruments and measurement protocols to be adopted, across different ecosystems; iii) to promote the use of a common 'smart' on-line spectral information system to share standardized proximal sensing data and products with other scientific communities (FLUXNET, ICOS, FLEX); iv) to develop a framework in the on-line system for consolidated metadata for specific ecosystem types and applications; v) to bridge the gap between in-situ measurements and satellite sensor data by promoting the development and use of UAV-based observation and their integration with modeling approaches for monitoring and investigating ecosystem functioning across differing temporal and spatial scales, leading to the better exploitation of satellite data; vi) to support the RS activities focused on steady-state fluorescence and the FLuorescence EXplorer (FLEX) mission, promoting, coordinating, and disseminating the results of validation and calibrations campaigns.

## C.3 How networking within the Action will yield the objectives?

This Action has already secured the interest of research centres across COST countries, and will continue to work on expansion, including Near Neighbour Countries, Reciprocal Agreement Countries, and International Partner Countries (IPC). To capitalize on its geographic scope and promote wider involvement, Working Group and Management Committee Meetings, Training Schools and Short Term Scientific Missions (STSMs) will be conducted across participating COST countries during the course of this Action. Individual research centers have already expressed interest in organizing and committing the necessary resources for these meetings and activities. These Institutes have on-going nationally funded projects and PhD programmes and are committing at least one senior researcher to this network. Therefore, the means to secure the Action’s objectives in terms of human resources, time and funding are already secured through national programmes. In addition, the partner institutes, in collaboration with the scientific instrument and UAV manufacturers and other networks (FLEX, EUFAR, ICOS), will provide the hardware resources (spectroradiometers, UAVs, aircrafts and instruments, EC towers) needed for the Action activities.

The benefits of carrying out the project within the COST Action framework are: i) establish stronger European proximal sensing infrastructure through meetings and networking i) train world-class scientists through network meetings, STSMs, Training Schools and joint research activities); iii) a higher degree of connection between the European networks and overseas initiatives through the involvement of Reciprocal Agreement/International Partner Countries (IPC) , and the participation of top-class international scientists at the meetings and as External Experts or Training School trainers; iv) promoting the standardization of sampling protocols and instrumentation throughout COST countries; v) wider dissemination of the network activities through inter-network meetings and knowledge exchange with industries (scientific instrument and UAV manufacturers). Furthermore, this Action will collaborate with SPECNET, providing a global integration of networks, and participate in joint field campaigns planned for the next summers.

**C.4 Potential impact of the Action**

This Action will have a positive impact by supporting the ICOS network by focusing on proximal sensing observations and encouraging the use of common protocols and a data sharing platform to stimulate standardization of tools and scientific methods. Young optical sampling researchers will be trained during spectroscopy and biophysical measurement Training Schools and STSMs, focusing on optical sampling from UAVs. FLUXNET, the "network of networks" which coordinates regional and global analysis of observations from micrometeorological tower sites, will also engage with this Action: FLUXNET delegates have already expressed their interest in participating as external experts or Training School trainers. In addition, positive interaction between the scientific community and the instruments industry (spectrometers and UAVs) will be enabled by this Action. In particular, Working Group (WG) 2 will foster collaboration between the research community and the scientific instrument industry, started within the EUROSPEC WG 3. Within this Action, WG2 will test new prototypes (e.g. a miniaturized hyperspectral system for use on UAVs or EC towers), facilitating the commercial availability of such sensors. Use of these new instruments will provide important new datasets for climate change studies and ground, airborne and satellite fluorescence observations. These data will also provide a database for satellite (FLEX, Sentinels) product validation. Finally, the creation of a dataset with standardized processing will facilitate for data integration, help link the empirical and modeling studies and provide data end users with a well-structured and easy to access database, enabling more collaborative and transparent scientific research among the FLUXNET, ICOS, SPECNET, and FLEX networks and the wider scientific community. This will be highly relevant to the European Earth Observation community in the coming years , the launch of the Sentinel series of satellites is scheduled for 2014.

### C.5 Target groups/end users

This Action will target the optical RS and the biogeochemical measurement and modeling communities and provide a link between these research areas, contributing to the validation the RS observations and modeling products. The training of ESRs from these communities will be a focus of this Action, and their participation in STSMs and Training Schools as well as WG meetings will be encouraged. Action members will become part of a ICOS advisory group. This Action will provide advice to ICOS on the technical and scientific implementation of hyperspectral continuous and UAV-based measurements at the EC sites. Developments, through near-ground measurement network, will lead to a fuller exploitation of data from Earth Explorer Missions like FLEX, and the new ESA programme for Scientific Exploitation of Operational Missions (SEOM), and provision for the validation of satellite products. This Action will also engage with the scientific instrument industry to provide feedback on current instrument systems and promote the development of innovative new systems to be exploited commercially. The use of these scientific instruments mounted on UAVs, will be a significant step to improve the standard of optical measurements and ecosystem observations. Delegates from the scientific instruments and UAVs industries will be invited to participate to all meetings and in Training Schools.

## D. SCIENTIFIC PROGRAMME

### D.1 Scientific focus

This Action will investigate the relationships between reflectance and fluorescence measurements and the biophysical and ecophysiological properties of Earth surfaces both in the spectral and spatial domains. Innovative new miniature hyperspectal sensor systems mounted on pointable gimbals on rotary-wing UAVs and at fixed locations will be used. This work will be carried out at existing carbon and water vapor flux research sites across Europe. In addition, a 'smart' on-lineportal will provide access to a database to which data from both optical and ancillary sensors will be automatically and wirelessly uploaded. This portal will also provide access to quality assured data products with appropriate uncertainty estimate made explicate.

### D.2 Scientific work plan methods and means

The following scientific activities will be carried out by 3 Working Groups:

WG1. Spectral information system: metadata set definition, automated data collection, storage, quality assurance checks and uncertainty estimates, information building and model data integration.

The use of a new common central information system to combine in-situ and spatial data/metadata and to enhance the harmonisation of exchange mechanisms will be investigated and tested within the Action network. Essentially, the system must support the data life cycle of spectroradiometric data, namely: data acquisition, data processing, metadata augmentation, information building, and do so in a 'smart' manner minimising manual input, and information retrieval mechanisms. Techniques for the automatic filtering of data from flux tower and UAV sensors which will selectively decimate, compress and forward data dependent on the available bandwidth and the qualities of the data will be investigated. Techniques currently under development for the intelligent capture and transmission of weather station data (intended to optimize power usage and data quality) will be examined for suitability in the case of in-situ spectroradiometric measurements and UAVs data. Also the ability to automatically endow measurements with metadata concerning the types of equipment used and circumstances of data collection and subsequent automated integration of this data into SPECCHIO will both improve the validity of individual data sets and allow valid comparisons across data sets captured at different sites and using different equipment and regimes. The following five activities will be conducted: 1) Definition of a metadata set including a mandatory core set to document the particularities of ecophysiological spectral data. This metadata set will be aligned with general metadata sets of the in-situ spectroscopy community on an international level. The metadata set definition is expected to be an evolving standard based on best-practice throughout the duration of the Action. 2) Definition and implementation of a dataflow from in-situ sensors to the spectral information system, submitting spectral data and available metadata in an automated fashion to allow for product generation downstream. 3) Definition and implementation of data pre-processing and metadata augmentation including data flagging and filtering the support information building. This will also include the development on methodologies and according implementation for quality assessment and data check of ground spectral data by integrating metadata, auxiliary information and other radiation measurements available from existing eddy covariance databases. 4) Development and implementation of information building functions that increase the information within the database by processing of available spectral data, metadata and auxiliary information where available. 5) Implementation of data retrieval and spectral data assimilation into biogeochemical modeling, flux data spatialisation and linking space-sensed data with precise localised flux and spectral data.

The spectral information system implementing the above will be tested for some of the ICOS-reflectance sites to demonstrate its practical application and feasibility. The system will be based upon the latest version of the SPECCHIO spectral information system (Hueni, Nieke et al. 2009; Hueni, Malthus et al. 2011), which was recently redesigned and significantly enhanced by projects sponsored through the Australian National Data Service (ANDS) and the COST Action ES0903 (Hueni, Chisholm et al. 2012).

WG1 Deliverables:

i) Definition of a mandatory metadata set, aligned with current international efforts in the spectroscopy community

ii) Develop an on-line instance of a spectral information database to serve as demonstration and testing platform for data sharing and information building

iii) Develop a wireless automated dataflow from *in-situ* and UAV sensor for the database system

iv) Definition and implementation of data pre-processing and metadata augmentation algorithms and routines including quality checks and flagging and data assimilation

v) Definition and implementation of system interfaces and algorithms for data retrieval allowing the building of products using sources such as biogeochemical modeling, flux data spatialisation and space-sensed data.

WG2) UAVs: Unmanned Aerial Vehicles for upscaling proximal sensing ecosystem observations by means of model data integration.

UAV technologies are progressing rapidly and these offer low-cost, relatively stable platforms that are capable of flying low and slow to capture detailed near-canopy information at potentially fine spatial resolution. UAVs can now be configured to carry a range of different payloads including thermal cameras, miniaturized hyperspectral spectroradiometers and standard visible or infra-red cameras. However, such approaches have not yet been extensively tested and validated at study sites and data acquired from these platforms will require to be integrated into datasets derived from fixed-point optical sesnors mounted on flux towers.

There are many advantages to using UAVs as platforms for this type of research and the following will be investigated:

a) If the cost is significantly lower than manned aircraft flights;

b) the flights can be user-controlled in both spatial and temporal terms, meaning that the most scale-appropriate data can potentially be obtained;

c) UAVs by being able to fly low and slow can 'bridge' the scaling gap between the fixed-point discrete ground-based observations and those made by satellites by providing 'within-pixel' estimates of spatial or temporal variability and therefore carrying information about ecosystem processes happening at smaller and faster scales than those that can be investigated with satellite data;

d) multi-rotor UAVs can hover over fixed points and if operated at different altitudes provides an unique opportunity investigate spatial aggregation effects studies.

The introduction of such systems will facilitate the use of data rich pilot sites for calibrating empirical models and tackling the challenges of up-scaling methods. UAV flights will provide a fine scale spectral characterization of ecosystems at landscape scale. The integration of UAV based approaches will provide data in the spatial dimension with fixed-point approaches (e.g.EC or Phenological Cameras) providing data in the temporal dimension, exploiting the strengths of each method for the estimation of the spatial-temporal evolution of ecosystem processes. Such an approach is of great advantage for discriminating the sources of energy/matter fluxes in heterogeneous ecosystems allowing for performing ecosystem type specific model data fusion processes. This will be key to reducing uncertainties in up-scaling exercises and more generally for environmental monitoring purposes.

The first task in this WG is therefore to test the use of UAV platform at a series of test sites, carrying out (nadir and multi-angular) reflectance and fluorescence observations. This will allow the relationships between the ecosystem biophysical parameters, the matter/energy fluxes and the spectral information to be investigated using empirical approaches based on specific spectral bands and/or bands combinations (e.g. Photochemical Reflectance Index; Normalised Difference Vegetation Index) as well as machine learning approaches and coupled radiative transfer models with biogeochemical ones.

This WP will be divided into three distinct Activities:

1) UAV platforms: the task in this activity is therefore to test the use of UAV platform at a series of pilot sites, carrying out (nadir and multi-angular) reflectance and fluorescence observations and assess positional accuracy of current GPS control systems. 2) Model Data Integration: this activity aims to calibrate data driven and process based models using in-situ data and comparing/integrating them with the estimates provided by UAV platforms 3) Up-scaling: functional relationships and calibrated model parameters will be linked to regional drivers for estimating biophysical properties of vegetation at broader scale. Furthermore the benchmarking with machine learning methods will permit to evaluate the robustness of the estimates. Eventually, models that simulate hyperspectral reflectance in conjunction with the exchange of $CO_2$, water vapor and energy can be coupled to footprint models to create a 'footprint simulator', which would allow the seamless integration of EC flux and spatial explicit data from UAVs.

WG 2 deliverables:

i) Review and report on the challenges for optical sensing in up-scaling biophysical properties of vegetation and test different UAV platform/measurement instruments setups

ii) Development of a footprint tool for optimalplacement of fixed spectrometers and for combination of EC measurements with UAV-based spectral data

iii) Liaise with industry representatives to improve accuracy of GPS

iv) Definition of new methods for scaling up functional relationships between optical properties and ecosystem processes from in-situ to landscape scale by means of UAVs, including identification of adequate radiative transfer models to be coupled with biogeochemical models for linking biogeophysical properties of vegetation with its optical properties.

WG3 Reflectance and fluorescence: integrating proximal sensing reflectance and fluorescence observations).

Proximal sensing reflectance, solar-induced fluorescence, water and carbon fluxes measurements carried out at the EC towers will be integrated with the aim of investigating the mechanisms regulating light use efficiency and to build a ground validation network for satellite observations (FLEX, Sentinels) and Earth System Models. Efforts will be devoted to the comparison between different methods used by the scientific community to estimate the solar-induced fluorescence from passive remote measurements. This WP will be divided into four distinct activities: 1) Efforts will be devoted to the comparison between different methods used by the scientific community to estimate the solar-induced fluorescence from passive remote measurements. A review of existing methods and instruments for fluorescence retrieval from high spectral resolution radiances of vegetation that have been described in the scientific literature. Besides standard Fraunhofer Line Depth (FLD) approach, which assumes constant fluorescence and reflectance factor in the Fraunhofer line, other methods such as spectral fitting techniques aimed to overcome the limitations given by FLD assumptions will be investigated. In particular, the instrument requirements in terms of spectral resolution, sampling characteristics and signal to noise ratio to accurately retrieve fluorescence with different methods will be evaluated. 2) A key objective will be the implementation of specific technical requirements for fluorescence and reflectance measurements from ground and UAV-installed instruments. An atmospheric correction scheme for fluorescence retrieval from UAV-platform will be also evaluated, 3) A list of existing fluorescence datasets coupled with hyperspectral reflectance and photosynthesis/productivity measurements will be compiled. This database will allow time-series generation of key optical properties related to the photosynthetic activity of the vegetation for a representative number of sites throughout different vegetation types, spanning a wide variety of ecosystems. These data, collected by a central capability, will be essential to understand how the relations between fluorescence, reflectance and productivity hold and change across different ecosystems and structures, different illumination and temperature conditions, different stress and management, and different spatial and temporal scale of investigation. 4)The integration of fluorescence, spectral reflectance and productivity data will be acquired with a multiple scale approach from plant/canopy level to regional scale, using field, tower, UAV, airborne and spaceborne instruments to measure all the different components and their uncertainty. These data will be then used to find and test alternative ways to parameterize photosynthesis Light Use Efficiency models with the aim of developing new approaches based only on measured data and without any prescribed functional response of productivity in respect to the environmental driving factors.

WG 3: Reflectance and Fluorescence deliverables:

i) Review and report on the methods and instruments used to estimate the solar-induced fluorescence from passive remote measurements

ii) Definition of the technical requirements and acquisition protocols for reflectance and fluorescence measurements from UAV and ground-based instruments

iii) Database of reflectance, fluorescence and productivity data for later use in models and applications

iv) Integration of ground and UAV measurements with biochemical model outputs to better understand the links between photosynthesis, plant stress, growth and physiology with the temporal dynamics of reflectance and fluorescence.

## E. ORGANISATION

### E.1 Coordination and organisation

This Action will be for 4 years, a management committee (MC) and WGs, with co-ordinators, will be formed and an Action Chair and Vice-Chair appointed by members and an administrative Action Manager will be appointed. This Action will coordinate and build on the research carried out in and financed by the participating countries. The Chair, the Vice-Chair and WG coordinators will form the Core Group (CG) to handle operational and protocol issues in order to: i) enhance the interaction between the WGs; ii) facilitate the application-participation of Near Neighbour Countries and International Partner Countries (IPC) ; iii) setup the STSM evaluation criteria ad monitor the activities of the STSM Evaluation Group; iv) monitor the website and serve the needs of Action members and the general scientific community; v) ensure the dissemination of Action outputs and regularly update dissemination plan; vi) act as an editorial committee for publications (e.g. joint papers, special issues).

The MC will meet once a year, as a minimum, and will be responsible for: research topics selection, WGs creation and monitoring, project budget monitoring, developing a plan for dissemination results and Action progress reports, gender balance and EarlyStage Researcher involvement, and both Annual and Final Report preparation. The MC (the representatives of signatories MoU) will nominate a Chair and a Vice-Chair to be responsible for coordinating activities and ensuring that the Action direction meets the overall objectives. The Action will establish an interactive website that will be a primary tool for coordination, scheduling, planning, implementation, documentation, dissemination. Information about relevant publications, reports, contacts will be published on the website and updated on a regular basis. The site will include links external research programmes (ICOS, FluxNet etc). During MC meetings, the Chair will address and report on the progress of the different WGs. The MC will monitor the preparation of both Annual and Final Reports. A STSMs Evaluation Group (STSMs EG) will also be appointed by the MC, in to promptly evaluate STSM applications and review subsequent reports. Criteria and a template for the STSM candidate selection and proposal submission will be developed by the STSMs EG.

**E.2 Working Groups**

Three WGs will be created: WG 1: Spectral Information  Systems; WG 2: Unmanned Aerial Vehicles (UAVs); WG 3: Reflectance and Fluorescence measurement. Each WG, will have a coordinator and a vice-coordinator nominated by the MC, and selected according to their scientific expertise and organisational skills. WG co-ordinators will ensure that each group has balanced geographical and gender representation. For each WG, 2 coordinators (when possible, 1 coordinator will be a young scientist) will be elected by the MC and members selected according to their scientific expertise and organisational skills. The WG coordinators will coordinate activities in their scientific domain and integrate activities and networking across the Action and produce reports on the progress of the activities to the MC annually. Annual plenary workshops will also be organised by the WGs and industry Action members and representatives will be invited to participate. Each WGs will also hold a themed Training School and promote the training of young scientists.

**E.3 Liaison and interaction with other research programmes**

This Action provides an opportunity to connect the proximal sensing, biophysical and ecophysiological, optical remote sensing and the carbon and water vapor flux networks and communities. Liaisons and active interactions are expected with the following research programmes/networks: i) Integrated Carbon Observation System (ICOS): the Action will support the implementation of reflectance and fluorescence measurements at the ICOS sites, providing technical documentation, focused papers and detailed reports. The ICOS advisor, nominated by the MC, will act as a bridge between the two networks and participate in all relevant ICOS meetings; ii) FLEX: WG 3 will organise focused meetings, fluorescence validation campaigns and promote focused STSMs; iii) SPECNET, FLUXNET: the Action network will interact with these global networks inviting some key-delegates to focused meetings, plenary conferences and as trainers/trainees to the Training Schools; iv) COST Action 2100 (ICT): WG 2 will organise a joint event on the use of wireless communications within the proximal sensing networks and ; v) EUFAR: a Training School will be co-funded by EUFAR . Join flight campaigns will be organised: the Action will provide manpower and instrumentation for ground validation activities; vi) ICOS-INWIRE: key-delegates will be invited to focused meetings, plenary conferences and as trainers/trainees to the Training Schools. focused meetings and STSMs will be organized. vii) WG1 will further metadata definitions in consultation with CSIRO, Australia, and NASA, USA, who are already working in the metadata domain and have invited members of this Action to collaborate.

**E.4 Gender balance and involvement ofEarly-Stage Researchers**

“This Action will respect an appropriate gender balance in all its activities and the Management Committee will place this as a standard item on all its MC agendas. The Action will also be committed to considerably involve Early-Stage Researchers. This item will also be placed as a standard item on all MC agendas.”

This Action will respect an appropriate gender balance in all its activities, and will place this as a standard item on all its MC agendas. This Action will ensure that female lead scientists members will be given leadership roles. The Action will also be committed to ensuring the involvement of Early-Stage Researchers, promoting data sharing and networking opportunities. These items will also be placed as a standard item on all MC agendas. STSMs organised during this Action will promote the training of young scientists, with an emphasis on scientists from less-developed European regions. Training Schools will provide the primary mechanism to train Early Stage Researchers and actively promote their involvement in the Action's activities. The MC will, from the start of the Action, actively stimulate Early Stage Researchers to participate to the STSMs and Training Schools and WG meetings to present their work, and contribute to WGs activities and will seek a gender balance at this level of activity as well.

**F. TIMETABLE**

The duration of the Action will be 4 years. During the first year, special attention will be given to the Spectral Information Systems (WG1) scientific activities; the second year will be mainly focused on UAvs (WG2), while Reflectance and Fluorescence measurements (WG3) will be the main topic of the third year. The final conference will be organised as a joint event by the 3 WGs as will production of final report and scientific publications.

| | **Phase 1 (year 1, 12 months)** | **Phase 2 (year 2, 3; 24 months)** | **Phase 3 (year 4, 12 months)** |
|---|---|---|---|
| **MC** | Establishing WGs, Chair and Vice-Chair, Core Group and defining initial work and activities .Organisation of 1st Plenary Conference. Developing COST website. Start of STSMs | Organisation of 2nd and 3rd Plenary Conferences +join meetings. Monitoring WGs activities and Report on the progress annually. Monitoring STSMs . Dissemination of results. Organizing Joint Workshops with other networks | Organisation of the 4th year Plenary Conference + join meetings. Monitoring WGs activities and Report on the progress annually. Proceedings of the 2nd 3rd and 4th Plenary Conference. Dissemination of results. Completion of the Final Report |
| **CG** | i) enhance the interaction between the WGs. ii) facilitate the application-participation of Near Neighbour Countries and International Partner Countries. iii) setup the STSM evaluation criteria. iv) monitor & update website v) act as an editorial committee to monitor the quality of dissemination | i) enhance the interaction between the WGs.ii) facilitate participation of Near Neighbour Countries and International Partner Countries iii) monitor the website and keep it up to date. iv) act as an editorial committee to monitor the quality of dissemination | i) enhance the interaction between the WGs. ii) facilitate the application-participation of Near Neighbour Countries and International Partner Countries. iii) monitor the website and keep it up to date. iv) act as an editorial committee to monitor the quality of dissemination |
| **WG1** | Co-organisation of 1st Plenary Conference. Development of a work plan based on MC indications. Production of reports on Spectral Information Systems activities | Producing reports on Spectral Information Systems .Dissemination of results | Co-organisation of the Final Conference. Contribution to the Final Report preparation. Dissemination of results |
| WG2 | Development of work plan based on MC activities. Producing reports on UAVs | Co-organisation of 2nd Plenary Conference. Producing reports on UAVs | Co-organisation of the Final Conference. Contribution to the Final Report preparation. Dissemination of results. |

| | | | |
|---|---|---|---|
| | activities every 12 months. Dissemination of results. | activities. Dissemination of results | |
| WG3 | Development of a work plan based on MC activities. Producing reports on Reflectance & Fluorescence. Dissemination of results | Co-organisation of 3rd Plenary Conference. Producing reports on Reflectance & Fluorescence activities. Dissemination of results | Co-organisation of the Final Conference. Contribution to the Final Report preparation. Dissemination of results |

## G. ECONOMIC DIMENSION

The following COST countries have actively participated in the preparation of the Action or otherwise indicated their interest: AT, BE, CH, DE, ES, FI, IT, NL, PL, PT, SE, UK. On the basis of national estimates, the economic dimension of the activities to be carried out under the Action has been estimated at 48 Million € for the total duration of the Action. This estimate is valid under the assumption that all the countries mentioned above but no other countries will participate in the Action. Any departure from this will change the total cost accordingly.

## H. DISSEMINATION PLAN

### H.1 Who?

Target audiences for the dissemination of the results include: All the research community working in the proximal sensing field (EU and non-EU), relying on the optical observations for estimation and upscaling of biophysical and flux observations. This community involves scientists working in the carbon exchange field, biogeochemical modelers, radiation modelers, and precision agriculture centers. These existing networks have been directly involved in the proposal development.
The Action will disseminate results and finding through current networks such as, but not limited to, ICOS, FluxNet, and SpecNet. Ouputs will also be disseminated through Earth Explorer Missions communities such as FLEX, Sentinel and the new ESA programme for Scientific Exploitation of Operational Missions (SEOM). Some new members also have interests in precision agriculture and arboriculture, therefore knowledge gained in this Action will be disseminated across other COST domains. In addition, outputs will be disseminated though scientific instrument and UAV industries. This will enable opportunities to coordinate developments with the research community needs and to collaborate with the Action Working Groups towards the commercialisation of prototype tested by research groups. EU and government policy makers, as well as the general public, will be kept

informed about the state of the art of the Action activities. Policy fields addressed are mitigation of greenhouse gases, managing global change, remote sensing and environmental management.

**H.2 What?**

The dissemination strategy consists of the following:
Plenary workshops and joint meetings will be organised including experts, Early Stage Researchers, end users, policy makers, representatives of the European and global networks, end users, policy makers. Focused workshops organised by the WGs (and suggested by the other networks) will focus on specific scientific issues.
A fundamental role will be assigned to publishing the results in scientific papers. The publication of joint papers will be promoted, coordinated and monitored by the Core Group. A final special issue will be organised. The state-of-the-art instrument and platform developments and the results of the Action will be published through the Action website, designed to maintain an efficient research network, and keep the media and the general public informed about the Action activities. The website will include general information, technical documents, reports, joint papers, and will facilitate data sharing through a link with the Spectral Information System database (see WG1). Measurement standard procedures and protocols will be also published in the website and available to the community. Information will be provided through brochures, article press releases, newsletters from various communities (SpecNet, ICOS, IPCC, CMCC). Three Summer Schools will be organized to introduce young scientists in the challenges involved in integrating proximal sensing and in upscaling ecosystem observations. According to the research needs, the industries will be invited to participate to all the relevant Action activities. In some cases, the collaboration might lead to instruments upgrades and new prototypes, towards large-scale instruments production.

**H.3 How?**

Focused workshops including experts, Early Stage Researchers, end users, policy makers, representatives of the European and global networks, end users, policy makers, will bring together different approaches and ensure a positive dissemination of the Action results among different expertises. In addition, the Plenary Conferences, together with other Joint meetings (where delegates of other relevant networks will be invited), will be useful to disseminate the results of the Action across the difference science and technology communities. During the Action, the website will be set up as a fundamental electronic communication network. The site will be linked to all the other networks introduced in this proposal. During the Action, the state-of-the-art instruments and methods and the main results will be published on the website on a regular basis under supervision of the Core Group. The media will be fundamental to inform the general public and the stakeholders about the Action activities and findings. Review papers/Special Issues will provide an analysis and synthesis of the current state of the proximal sensing measurements sites, data handling, metadata, informatics issues, UAVs technology, and fluorescence research. Focused bi-lateral meetings, when needed, will be organised with the scientific instruments industries to analyze prototypes and to consider large-scale production. To disseminate the results of the Action, joint publications will be organized. At the end of the Action, a final Special Issue will be prepared, including the most relevant results of the Action activities.