Minutes of the kick-of meeting of the SENSECO WG1 activities

(4 February 2019, Brno, Czech Republic, hotel BWP Premier)

Participants:

1. Shari van Wittenberghe
2. Maria Pilar Cendrero-Mateo
3. Javier Pacheco-Labrador
4. Luis Alonso
5. Matti Mõttus
6. Adrian Moncholi
7. Martin Schlerf
8. Dusan Lazar
9. Tomas Furst
10. David Fuente Herraiz
11. David Vinue Visus
12. Abdelaziz Kallel
13. Hideki Kobayashi
14. Jochem Verrelst
15. Zbyněk Malenovský
16. Zoltan Nagy
17. Krisztina Pinter
18. Alberto Hornero
19. Corine Davids
20. Enrico Tomelleri
21. Charlotte de Grave
22. Pablo Morcillo

Session 1 - Introduction of the cost action "SENSECO" – by Jochem Verrelst, talking on behalf of the chair Martin Schlerf

Focus on satellite data: Sent-2, Sent-3, upcoming FLEX mission. Development of retrieval and scaling methods. Make use of physical models: leaf and canopy RTMs, may be integrated in larger ecosystem models. Use of synergy of different model types and datasets to answer the question of spatially and temporally quantifying vegetation dynamics. With support of drones and EC towers. Key topics: How to scale between coarse and fine resolution data, how to harmonize between different models, find an agreement on retrieval protocols, provide multisensory datasets.

4 working groups: 1) closing scaling gap; 2) closing temporal gap; 3) sensor synergy; 4)quality of data; interactions between different WG's.

- Introduction of the Scaling WG1 activities and questionnaire – by Maria Pilar Cendrero-Mateo

Aims of WG1: Put together measurement and modelling communities and assess the gaps to be filled, the needs of both communities. Coming with consistent protocols for measurement and retrieval of vegetation parameters

Reminder on how cost action works, anyone can propose a project within the covered topics and receive a funding (see website). Organization of summer schools is encouraged.

Presentation of a questionnaire that will be first passed through the people present and can then be spread to the colleagues. Data gathered will be presented on first annual meeting of WG1 end of March. Other workshop will be organized in the second half of 2019, with focus on how to improve the estimation of biophysical and biochemical traits and which are the most relevant ones. These questions are integrated in the questionnaire. Other future activities: cal/val protocols for biophysical/biochemical traits. This will be integrated into a summer school in 2020, in collaboration with WG2 with main aim: to educate students and test protocols on the field. It is encouraged to spread the word on this summer school.

- Introduction of all participants (and their expectations regarding this first meeting)

Main expectations: to standardize procedures; to obtain a closer link between scientists doing measurements at different levels (leaf-canopy-EC tower-drone-airborne-satellite) and modellers simulating active photosynthesis and fluorescence in order to be on the same page; to compare fluorescence models; to learn on different RTM's; to have an overview on other research topics; to look for cooperation e.g. on time series of fluorescence and spectral features; how to separate soil from vegetation signals; to brainstorm on forward modelling of physiological processes based on spectroscopy; to address scaling issue; to enlarge my view of fluorescence in RTM modelling to a more ecological and biological point of view.

- Scanning through the questionnaire

Add "other" field in list of questions + blank space to let people add comments

Discussion on other aim of Cost: develop an online platform to share data. Existing platform SPECCHIO (www.specchio.ch): partly open database; last cost action enabled to develop the database and create a protocol on how to share and access data; other aim of Senseco: to make a link between Specchio and Artmo; ongoing development of a similar platform for fluorescence by Julich/A. Damm

Some parts of the questionnaire need some clarifications or rephrasing.

<u>Session 2 – Vegetation traits and leaf RT models</u>

- Measurements and datasets of leaf traits for parameterization of leaf-to-canopy scaling - Shari van Wittenberghe

Importance of leaf-level mechanisms for upscaling to canopy level. Energy dissipation mechanisms in case of excessive absorbed light: chlorophyll fluorescence, heat dissipation, NPQ. Photoprotective mechanisms are responsible for nonlinear relationship between fluorescence and photosynthesis. Importance of carotenoids in NPQ. Amount of absorbed light depending on pigment pool and its seasonal dynamics. Absorbance spectra of pigments can vary in vivo. In models, one general spectrum for each pigment is used, which is a combination of different spectra together. Pigment spectral features not integrated, we can only derive total amount of each pigment. Not possible to distinguish different carotenoid pools. Dynamics of pigment pools when leaf is subjected to intense light: decrease of reflectance at 530nm linked to chemical conversion of the carotenoid pools and is an indicator of proton gradient, another absorption feature happening later in time and at higher wavelength and across the whole spectrum, somehow also linked to the strategy of the plant to cope with excess light, this feature is overlapping with signal. Integrate these absorbance spectral features in models to distinguish different carotenoid pools and to take into account their dynamics. We need stable instruments to detect these small, although perfectly detectable, mechanisms. Leaf temperature should be integrated in measurement protocols.

- Measurements and datasets of canopy traits for parameterization and validation of scaling activities - Maria Pilar Cendrero-Mateo

Canopy reflectance and fluorescence driven by leaf reabsorption and scattering mechanisms by structural elements and soil. Fluorescence is a residual, it is the amount of light reemitted by plants that was not dissipated as heat. Experiment of FLEX campaign, results coming from a collaboration inside Optimize cost action. Soja plants growing in fields with two different chlorophyll (chl) content but with similar net photosynthesis at leaf level. Plants with higher chl content (Eiko/wild type) had higher levels of APAR and NPQ but showed lower photosynthetic efficiency. In the Minggold variant with lower chl content, the light could reach the chl molecules that are deeper in the leaf and use them more efficiently as in the Eiko variant, the upper chl molecules saturated quickly and had to dissipate more heat. First peak of fluorescence similar in both varieties but bigger second peak in wild type. Field measurements to see if same trends are visible at canopy level. Measurements of LAI, chl, distribution of leaf area at bottom, middle and top of canopy + measurement of upward and downward fluorescence + how much light absorbed/transmitted +fAPAR. Use of different spectroscopic systems. Use of SCOPE models to understand leaf and canopy level mechanisms. Higher leaf area in top canopy layers and higher fAPAR in Eiko. Fluorescence and fluorescence yield different in both varieties because of fluorescence reabsorption in leaves of Eiko variant. SCOPE used to test this hypothesis. SCOPE simulates fluorescence at 3 different levels (canopy: reabsorption of leaf and canopy, leaf: reabsorption of the leaf, photosystem: no reabsorption). Measured parameters (pigment spectra and structure) used as prior and model inverted to retrieve Cx (proxy for NPQ), N and fqe that were used as a prior to a second model inversion in order to retrieve LAI and LIDF parameters. Scope in forward model to simulate fluorescence at 3 levels and estimate GPP and FAPAR. SCOPE can reproduce measured trends but tends to overestimate values (APAR, NPQ). The question is to know how accurate is the APAR modelling in SCOPE because it is very important for fluorescence. Only one general SIF spectrum in SCOPE, but different spectra should be used for different parts of the canopy/leaf. Possible incorporation of “structural cover maps” as inputs for the model. Incorporation of dynamics of APAR, SIF, NPQ and photosynthesis both temporally and spatially through the canopy. Water use should also be accounted for.

- Short introduction about leaf SIF RT models + FLUSPECT CX – Zbyněk Malenovský

Different categories of leaf RTM’s: 1) Turbid medium models (e.g. LEAFMOD). 2) Plate models: leaf considered as plates separated by air (e.g. Prospect, Fluspect). 3) Needleleaf models, e.g. Liberty model: transmission not reliable, no active further development. 4) Ray tracing models e.g. Raytran. 5) Stochastic models (e.g Markov chain).

Prospect/Fluspect: semi-empirical; leaf mesophyll N and refractive index cannot be measured in vivo, inversion is needed; different N values for different leaf types needed as a priori knowledge. Prospect 6D: more specific absorption coefficients + attempt to separate pigments. Fluspect Cx: Introduction of fluorescence quantum efficiency (fqe) and of photochemical reflectance parameter as indicator of the carotenoid shifts; how were these parameters introduced? We get negative values at increasing light levels (sunlit leaves); forward modelling of fluorescence is difficult as we don’t know all the parameters that induce these values.

- Monte Carlo leaf model by Kallel – Abdelaziz Kallel

Mock-up divided in voxels and radiation traced for each voxel. Reflectance not lambertian, with specular effect. Transmittance almost lambertian. Modelling of upward and downward fluorescence. Fluorescence in the upward direction is higher than in the downward one. Upward fluorescence is due to palisade emission while downward fluorescence is due to both palisade and spongy emission. Fluorescence is minimal in nadir illumination and increases with incident angle because optical depth and number of contacts with chloroplasts also increase. Next steps: simulation of fluorescence art canopy level and validation of the model with field measurements. Discussion: but with higher incident angle, fAPAR diminishes which causes a decrease in fluorescence. This effect is not taken into account.

- Monte Carlo leaf model by Sušila and Nauš – Dušan Lazár

Model assumptions: Leaf is approximated by a 3D single homogeneous semi-infinite slab of a certain thickness and refractive index with homogeneously distributed interaction (absorption and scattering) centers. Absorption and scattering coefficients represent effective, volume averaged, absorption (scattering), by all presented types of absorbing (scattering) centers, and determine the probability of a photon to be absorbed (scattered) per unit path length. Photon packets are traced inside the slab as they are absorbed and scattered in the interaction centers.

Session 3 – Canopy RT models

- Short introduction about canopy SIF RT models – Jochem Verrelst

- SCOPE model by van der Tol, Verhoef and Young – Javier Pacheco-Labrador

Version 1.73 released 6 days ago, only small corrections compared to previous version. mSCOPE: allows vertical profiles of vegetation properties; for each layer, you can choose different fluspect parameters. Further development: Implementation of photosynthesis model and its temperature dependencies and adapt SCOPE to follow the biochemical implementation of the Community Land Model CLM4.5. The 1-D RTM approach presents some limitations but has also important advantages like processing speed and a limited number of involved parameters. The challenge of leaf RTM's still have to be solved as it affects the canopy RTM. An integral and comprehensive approach is needed to understand the mechanistic link between spectroradiometric signals, plant physiology, mass and energy transfer, as well on the VNIR part as on the thermal part of the spectrum. Discussion: Fractional vegetation cover is not included but is a very important structural parameter.

- FLIGHT model by North and Clemente – Alberto Hornero

3-D Monte Carlo ray tracing model. Less realistic than DART but faster. Applications: reflectance response of 3D vegetation canopies; photosynthesis model (LUE); LiDAR waveform; Inverse modelling for atmospheric and biophysical parameters retrieval; Fluorflight: Flight modified to account for fluorescence.

- DART model by Gastellu-Etchegorry et al. – Zbyněk Malenovský

Ongoing work: integrate fluorescence and polarization. Possible to integrate Python or C++ scripts. Landscape composed of repetitive elements. Works with two different 3-D objects: turbid cells or geometric triangles. The integration of structure is the most critical point in 3-D modelling. DART can compute the same kind of simulations as SCOPE but integrates a real 3-D view of canopy. Sun-adapted versus shaded-adapted leaves are better suited denominations than sunlit versus shaded leaves. Two different thresholds used to differentiate sunlit and shaded leaves. Photosynthetic process not yet integrated.

- SIF RT model by Kobayashi – Hideki Kobayashi

The model was part of the RAMI exercise. Own 3D Monte Carlo ray tracing canopy RTM model = Flies, with own leaf model based on other existing ones. Forest scenes created on which model is run. SIF can be modelled. Overestimations in spring and autumn. Very good agreement between measurements and modelled values but very noisy data were eliminated. Discussion: Spectral resolution of 10nm of the spectroradiometer which might be too coarse for fluorescence. You might see changes that are coming from other sources.

- Legacy of the RAMI (ROMI) exercise – Matti Mõttus

Original RAMI (RAMI I) in 1999, phase 2 of RAMI (RAMI II) was in 2002, RAMI III in 2005 and RAMI IV in 2009. End of the development phase of RAMI. Overall objectives of RAMI: to help developers improve their models; to provide a rationale for the acquisition of additional and higher-quality data; to develop a community consensus on the best ways to simulate the transfer of radiation at and near the Earth's surface and to exploit remote sensing data; to inform the user community on the performances of the various models.

RAMI IV: Assessing the reliability of physics-based RTM's under controlled experimental conditions. Results: Convergence of models within 1%. Models work well in virtual canopies but not in real canopies, which is ok but we have to agree on which are the inputs and have common definitions (e.g. leaf assumed to be bi-lambertian)

<u>Discussion</u>

- last RAMI was 10 years ago (2009), why is that? Paper writing. Organization is a lot of work.

- fluorescence modellers not ready for this kind of exercise. 1st step: "model cook-off"

- exercise can be done at leaf and canopy level in parallel

- you have to have the same atmosphere, the same solar incoming spectrum for all models but that is simple; but the location of the origin of fluorescence is different.

- separate leaf and canopy; leaf modellers are willing to take part of this exercise. Something could be done already at leaf scale. Nobody from Fluspect is present but the developers of the two others models are agreeing. But different models have different inputs. Shape of emission spectra should be the same for all models.

Much easier to compare canopy models because coming from the same principles. Start working group at leaf model to see if it is actually feasible. Everyone is agreeing. Coordinator needed. Only 3 models concerned, contact by mail should be enough. From refraction index, we can determine reflectance and transmittance, so it should be easy to compare the three models. There might be other models that could be included. The word should be spread.

Models should be compared to field measurements. But very low uncertainties are needed (measurement, instrumental). What are the data needed for the modellers? A lot of data is already available, need to identify what is useful and what is not for comparison of models with ground truth. Need for feedback on model assumptions.

Canopy: we do not have to compare only outgoing fluxes, but it can be taken as a first step, then we can move to other outputs like photosynthesis. There is interest to start a working group on the topic. The next Senseco meeting will be held end of March, where a lot of us will meet again. More time is actually needed to prepare a workshop on the topic and make announcement to involve more people (e.g. from Asia).

Organization of RAMI exercise is not to be underestimated, external resources needed like IEEE, Americans,… If we agree to do it, we should see how we will do it. We can organize a brainstorming within two months when we meet together again. There is already the article of Zbynek M. on the comparison between SCOPE and DART. Starting with 4 models being compared, two days can be enough.

FLEX workshop in Davos 6-8 March. We can have a meeting there.

- Closing words of the Chair