UV4Plants

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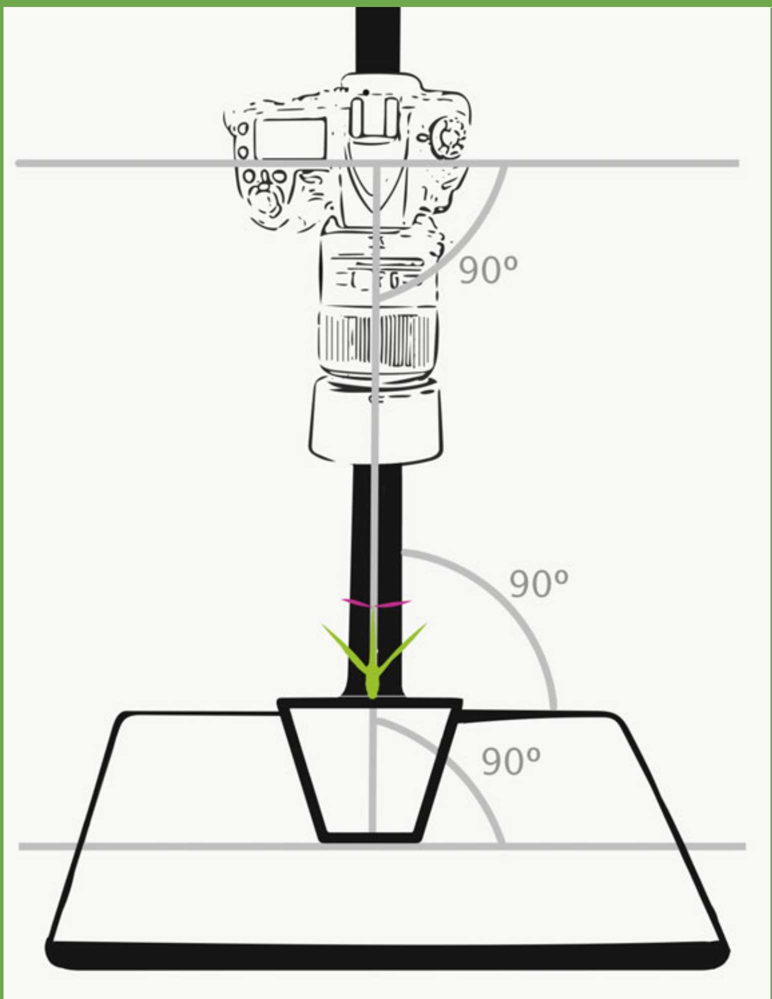

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Cover illustrations
Top-left: diagram of a copy stand (Fang Wang); top-right: a saguaro cactus (Steve Archer); bottom-left: Lars Olof Björn in Abisko, Sweden (Pedro J. Aphalo), bottom-right: Lars Olof Björn at the meeting of the UV4Growth COST Action, in Bled, Slovenia (Pedro J. Aphalo).

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Contents

From the editors' desk

Thoughts on the New Year

The New Year brings new opportunities and for many of us resolutions to improve in our work and our contribution to research. As Editors of the Bulletin, we hope to provide any extra stimulation and inspiration needed for you to be inventive in your ideas, meticulous in planning and novel in your hypotheses this year. So I encourage you to read the interesting variety of articles that we have put together in this issue, to apply the ideas they stimulate, and most of all to be ambitious in what you aim to achieve in 2017.

We must rise to the challenge of keeping plant-UV research relevant in today's highly-competitive academic environment. It is important to produce publications that represent meaningful scientific contributions for the research community, but also to reach out beyond our normal circle of academics, to communicate with non-scientists and the broader public, and spread this scientific knowledge to the community at large. Now more than ever, as we are seeing the consequences of poor communication of evidence-based scientific method and 'expert' judgement, we need to look to scientists for leadership in explaining contemporary issues and how they can be addressed through research. The chance to achieve something meaningful through science is illuminated when reading the great contribution to the Bulletin from Paul Barnes (page 7), and example of Lars Olof Björn as set out by Åke Strid (page 29).

Paul Barnes invites us to question the received view of UV radiation as harmful and offers us new perspectives on how we might consider UV in our research. Directing us towards some seminal references, he reflects on the history of plant-UV research in a treatise that should be required reading for both the PhD students new to the field and the experienced campaigner looking for inspiration. This article is nicely complemented by Lars-Olof Björn's self-effacing biography of his life as a scientist, which is a joy to read (page 17). The generosity and respect reciprocated in the testimonies of his colleagues cements the image of a fine scientist of great personal and professional integrity who can serve as an example for us to learn from and aspire towards.

If you resolve to learn new skills, this issue of the Bulletin is also a good place to start, and you might find that these skills are not as hard to master as you expected. You can find out how to model UV irradiance using libRadtran, whether as a means to validate measurements of solar radiation from your field sites or as a tool for better understanding of how location and atmospheric factors affect UV irradiance (Craig Brelsford, page 45); or open a window onto how wavelet analysis can be used to extract more information out of the spectral data that you collect than you might achieve with standard integrals (Agnieszka Jach, page 33); or if you want to improve your skills with image-J to better assess plant leaf area (Fang Wang, page 37), this is the place to do it!

As we have come to expect of Pedro J Aphalo, his review of the book OpenIntro Statistics is not simply a book review (and cautious recommendation I think; page 51), but provides insight into how to approach reading a statistics book in a way that gives us maximum benefit as a reader! One cannot fail to be caught up in Pedro's enthusiasm for this subject and he even includes a brief rubric of criteria to use when thinking of buying a stats book! It is not without reason that Paul Barnes reminds us of the need for well-

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designed experiments with high replication in plant UV research, as originally stated by Caldwell (1968).

With scientific rigour to the fore, we have from this issue implemented a peer-review process for submitted contributions to the Bulletin. The aim of this is to both ensure the high quality of our articles and to increase the attractiveness of the Bulletin for authors who might wish to submit their work with the hope of receiving constructive criticism from the plant-UV community, something which we will also draw upon you to give. Peer-reviewed articles are also of greater weight when it comes to assessments of your scientific output, so those articles which have been peer-reviewed are marked as such in the articles' footer. To further encourage submissions year-round, we have implemented an online-first publication system, whereby as soon as a piece is accepted it can be typeset and published online with that publication date. This will considerably speed up the time from submission to publication. Furthermore, articles published in the Bulletin are now indexed by Google Scholar.

We hope that these innovations will encourage researchers to take the opportunity to contribute to the Bulletin, and help to make the next issue as exciting and diverse as this one. We want to produce two issues a year of the Bulletin for UV4plants members, but we can only do this if you send in your contributions, whether they be whimsical or earnest thoughts on UV research: we want to hear from you!

T. Matthew Robson (editor)

Helsinki, February 2017.

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Letter from the President

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The publication of the last Bulletin coincided with our very successful conference in Pécs, Hungary organized by Éva Hideg and her team (Fig. 2.1). Personally I found the conference very enjoyable. It was wonderful to catch up with friends, to hear about recent research progress and to meet new members of the UV community. Moreover, to do so in very pleasant surroundings with plenty of sunshine and great hospitality all enhanced the experience. The feedback I received was that others attending also had a very enjoyable, productive time. There is no doubt that conferences generate momentum; the exposure to new information and ideas, the discussions with people with common interests, and the potential for new collaborations can influence research activity for months ahead. In addition, early career researchers can see how their work fits into the broader framework of UV research and they benefit from making new contacts in other labs.

We will hold another conference in 2018, but that is a long time to wait for our next UV 'fix'. Hence, one of the challenges we face in UV4Plants is thinking of the most effective ways to promote regular communication and interaction between our members. We try to do this through our webpage and social media, and of course the Bulletin is an excellent means of providing valuable information to members, but none of these is quite as effective as a conference. We are social animals and there is something special about being able to meet with people face to face, to engage in discussion of our research interests away from our usual commitments and distractions. Therefore, one of the things the UV4Plants managing group wants to do is to facilitate the organization of meetings and workshops that will help people develop interactions and exchange knowledge and expertise. These will be relatively small meetings focused on particular topics and could be designed to enhance practical skills. UV4Plants is inviting proposals from members to organize such meetings at any time – further information is on our webpage.

In addition, we have been active in organizing meetings in 2017 that hopefully will be attractive to UV4Plants members. Éva Hideg and I are organizing a symposium on UV-B-Stimulated Plant Protection at the European Society for Photobiology (ESP) Congress to be held in Pisa from 4th to 8th September 2017. The aim is to discuss how UV-B stimulates different aspects of plant protection, including against oxidative stress, pest attack and UV-damage. Our session will complement another ESP symposium on Photosynthesis and Photoreception. Details of the programme will be published by ESP and further information will be given on the UV4Plants website. In conjunction with the above symposia there will be a meeting organized by Annamaria Ranieri in Pisa. This meeting will discuss how UV-B research can be exploited for innovative and sustainable food production, and again information will be found on our website. The Pisa meetings will have complementary programmes and hopefully they will attract a good attendance. I therefore look forward to meeting old and new friends in September 2017. Pisa is a very attractive city

Figure 2.1: Conference participants, 30–31 May, 2016, Pécs, Hungary.

and there is bound to be a lot of exposure to UV-B both in the meetings and outside!

Finally, I hope you will enjoy reading this edition of the Bulletin. Production of the Bulletin involves a considerable effort by the Editors and they are always looking for new submissions. Please consider writing something yourself, however small, for the next edition.

Best wishes,

Gareth Jenkins
(President UV4Plants)

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News

First General Meeting

On 30 May 2016 the first General Meeting of UV4Plants convened at Pécs in conjunction with the first UV4Plants Conference. Fourty four members of the Association participated, or nearly 70% of the Association's members at the time. Several important decisions were made: the president and members of the management group were elected, the statutes of the UV4Plants Association were modified, the accounts for the previous period were approved, it was decided to organize a large conference on alternate years and Prof. Lars Olof Björn was named the first honorary member of the Association.

First UV4Plants conference

The first UV4Plants conference was held at Pécs, Hungary. The conference was very successfully organized by Éva Hideg and collaborators, with the steady support from the former president of UV4Plants, Marcel A. K. Jansen. The conference in numbers: 64 participants from 17 countries and 27 institutions. There were 28 oral presentations, and 22 posters presented. The book of abstracts is available at `http://uv4plants.org/repository/other/uv4pca-978-963-429-048-3.pdf`. A training school was organized immediately after the conference, with the participation of 23 students from seven countries and 11 different institutions. Galleries of photographs from both events can be found at the UV4Plants Association web site.

UV4Plants Conference 2018

An open call for conference organization proposals was advertised in January, three proposals were received, and the one led by Alenka Gaberščik, from Slovenia, was selected as the most beneficial for the Association and its members, and accepted.

Workshops in 2017

A call for proposals for workshops and training events is open, with no deadline for applications. For the latest information, please, visit the UV4Plants Association web site.

Open Journal System

An Open Journal Systems server (OJS, version 3) is now in operation for production of the UV4Plants Bulletin. This allows on-line management of the whole process from submission to publication. This system also automatically builds each article's web page with information suitable for indexing, and together with registration with Google, allows the contents of the Bulletin to be indexed by Google Scholar, and citations to articles in the Bulletin to be counted. The Bulletin's web site is at `http://bulletin.uv4plants.org`.

UV-B scientific meetings in 2017

Two conference sessions focused on UV-B research have been organized jointly by UV4Plants and the European Society for Photobiology (ESP) and will be part of the ESP Congress in Pisa in September 2017. UV4Plants is offering several bursaries to help members participate in these meetings. Please see the UV4Plants Association web site and ESP 2017 Congress website for information on the scientific sessions, registration and bursaries.

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TUV Quick UV calculator update

Sasha Madronich's TUV Quick UV calculator has been recently updated, and its URL has changed to http://cprm.acom.ucar.edu/Models/TUV/Interactive_TUV/. One important change is that the page now accepts a broader range of wavelengths allowing the simulation of the whole visible region of the solar spectrum in addition to the UV region available in the old page. It is still very important to be aware that *weighting functions are not extrapolated, and that for Caldwell's GPAS, Green formulation is not used, but instead Micheletti's one is used* (Sasha Madronich, pers. com. to Pedro J. Aphalo). This yields for TUV's output under "Plant damage (Caldwell, 1971)" a different, and smaller, value than the usually reported one for a given solar spectrum. For those using the r4photobiology suite of packages, the integrated output for GPAS of the TUV model corresponds to that obtained with the `GEN_M()` waveband definition from R package `photobiologyWavebands`.

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Historical account

Understanding the ecological role of solar ultraviolet radiation in the life (and death) of terrestrial plants: an historical perspective

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One of the over-arching goals of ecology is to understand how abiotic and biotic environmental factors influence the performance (evolutionary fitness), distribution and abundance of organisms in nature. Because there is a myriad of direct and indirect avenues by which environmental factors can potentially impact organisms, ecologists tend to focus their studies on a select few factors that are deemed to be most important in a particular habitat (i.e., they apply the concept of limiting factors to direct their research questions). Thus, plant ecologists give great attention to studying how water availability influences desert plants, how understorey forest plants have adapted to low light conditions, and how grazers impact grassland plants, etc. Perhaps because ultraviolet-B (UV-B; 280–315 nm) and ultraviolet-A (UV-A; 315–400 nm) radiation (hereafter collectively referred to as UV radiation) makeup seemingly minor parts of the solar spectrum at the earth's surface, ecologists have generally assumed that this radiation plays a rather minor role in the ecology of land plants. Indeed, even today UV is typically ignored in most introductory ecology and plant ecology textbooks, and if it does appear it is usually treated as a harmful environmental factor that plants must protect themselves against (e.g. Gurevitch et al. 2006). Consequently, most ecologists have a rather limited knowledge of UV photobiology and the techniques, instrumentation and literature specific to this field.

Consistent with the approach described above, early ecological studies on UV and plants examined UV effects in places where solar UV levels are naturally high, such as high elevation locations in Europe and North America (e.g. Brodführer 1955; Caldwell 1968). This research occurred during a time when physiological ecologists were keen to study plant adaptations in harsh environments, including the arctic and alpine tundra. There was also a push, under the auspices of the International Biological Program (IBP; 1964–1974), to understand factors controlling primary production in the major biomes of the world. However, even though alpine plants experience relatively high UV exposures, the earliest UV-exclusion experiments conducted in these habitats often revealed little if any detectable effect of ambient UV on the growth, morphology or reproduction of resident species (but see Caldwell 1968, for some effects on flowering in certain species). These findings pointed to a rather minor ecological role of UV in such systems and even raised questions about the value of these types of field filter experiments (i.e., if one can't detect effects of attenuating ambient UV in high UV environments is it likely that UV would elicit detectable effects in environments with much lower levels of UV?). And yet, comparative studies of ecotypes or closely related taxa that were distributed across a natural latitudinal/elevation UV gradient spanning low-elevation Arctic tundra in Alaska (low UV) to high-elevation tropical alpine tundra in Venezuela (high UV) revealed measurable differences in leaf optical properties, UV-absorbing compounds and physiological sensitivity to UV (Caldwell et al. 1982; Robberecht et al. 1980). These findings implied that UV, and in particular UV-B, was an important selective force in the evolution of these taxa and, moreover, that a relatively steep action spectrum was appropriate for plant responses to UV (Barnes et al. 1987). To be sure, elevation/latitudinal gradients differ in a number of environmental factors, including UV, so isolating the effects of UV on plants along these complex gradients is challenging. Nonetheless, these 'natural' UV experiments have continued to draw the attention of plant ecophysiologists interested in probing mechanisms of UV adaptation and acclimation (Nybakken et al. 2004; Ruhland et al. 2013; Sullivan et al. 1992). These types of studies are especially relevant today as plants are on the move in response to climate change (i.e., migrating to higher elevations and latitudes) and will likely occupy habitats in the future where they will be exposed to novel combinations of biotic and abiotic environmental factors, including UV. Understanding how UV influences plant performance and distribution in the context of a changing climate is thus an important area of research for ecologists today and into the future.

Concerns in the 1970–90's over the potential ecological effects of stratospheric ozone depletion and the associated increase in UV-B lead to a substantial increase in the level of UV research activities on plants during this time (Björn 2015) and also shifted the emphasis to specifically probe plant responses to enhanced UV-B. For obvious reasons, much, but not all, of this early ozone-depletion-related research examined the potential consequences of increased UV-B on economically important crop species (e.g. Biggs and Bartholic 1972; Caldwell 1972). The primary concern at this time was that enhanced UV-B might depress crop yield via partial inhibition of photosynthesis (i.e., increased UV-B→decreased photosynthesis→decreased plant yield), and results from many early laboratory studies generally supported this hypothesis (Brandle et al. 1977; Teramura 1983; Tevini et al. 1981). Improvements in the instruments used to measure UV-B (e.g., temperature-regulated scanning UV spectroradiometers), the development of sophisticated modulated UV lamp/filter supplementation systems (Caldwell et al. 1983) and refinements in action spectra/weighting functions (Flint and Caldwell 1996; Quaite et al. 1992) all improved our ability to provide for more realistic UV exposures to plants. In addition, the recognition that plant responses to UV were highly dependent on background levels of visible light (i.e., PAR; Mirecki and Teramura 1984; Warner and Caldwell 1983) lead some to question the ecological validity of findings obtained solely from greenhouse or growth chamber experiments (Caldwell and Flint 1994). Indeed, with some notable exceptions (e.g. Murali and Teramura 1986), results from field experiments have generally shown no pronounced negative effect of UV-B enhancement on photosynthesis and primary productivity (Ballaré et al. 2011). By comparison, exposure to enhanced UV-B consistently stimulated the production and accumulation of UV-absorbing compounds, and had subtle, but detectable, effects on shoot morphology without any apparent reductions in biomass production (Searles et al. 2001). These findings, and others, suggested that UV-B elicited specific photomorphogenic responses in plants that were distinct from more general "damage" responses (Ballaré et al. 1991). Over time, attention thus began to shift away from a focus on the negative

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effects of enhanced UV-B on productivity to understanding how these photomorphogenic effects of UV-B mediated species interactions (e.g., plant-plant competition; Barnes et al. 1995; and herbivory; McCloud and Berenbaum 1994). In addition, there was a growing recognition that plant responses to enhanced UV-B may well be influenced by other ongoing climate change factors (e.g., increased atmospheric CO_2). Thus, some began to explore the interactive effects of UV-B, CO_2, temperature, tropospheric ozone and other factors on both agronomic and wild species (e.g. Moody et al. 1997; Sullivan and Teramura 1994; Ziska and Teramura 1992).

Because ozone depletion was most acute at high latitudes there was a particular interest in evaluating the influence of altered UV-B (alone and with other climate change factors) on the plants and ecosystems of the Arctic, Antarctic and adjacent regions. Field studies at these locations utilized both UV-B-exclusion and UV-B-enhancement (i.e., lamps) approaches with the most extensive field efforts conducted on species occupying the Antarctic peninsula (Day et al. 2001), the sub-Antarctic vegetation of Tierra del Fuego, Argentina (Ballaré et al. 2001), and Arctic and sub-arctic ecosystems of northern Sweden (Björn et al. 1999). These studies not only examined plant responses to altered UV-B (Callaghan et al. 2004; Day et al. 1999; Searles et al. 1999), but also explored important ecosystem processes such as litter decomposition, herbivory and plant-microbe interactions (Gehrke et al. 1995; Robson et al. 2004; Rousseaux et al. 1998). Results from these and many subsequent studies conducted in a wide range of environments and UV-B exposures have shown that even ambient UV-B can influence plant performance, species interactions and litter decomposition though effects are often subtle and vary considerably with species and ecosystem type (e.g., Grammatikopoulos et al. 2001; Kotilainen et al. 2009; Rousseaux et al. 2004). It should be noted that the existence of seemingly small UV effects on plants does not necessarily imply minor ecological effects as small changes can accumulate over time (Robson et al. 2004) and be amplified via non-linear mechanisms (e.g., competition for light; Barnes et al. 2005). Having said this, well-designed experiments with high replication continue to be required for statistical detection of UV effects under field conditions—a caveat voiced nearly 50 years ago by Martyn Caldwell (1968).

With the implementation and subsequent strengthening of the Montreal Protocol, large-scale stratospheric ozone losses were avoided (Garcia et al. 2012) and research over the past several decades has returned to focus more on the fundamental roles of UV-B (and UV-A; e.g., Verdaguer et al. 2017) in influencing the growth and development of plants. An increased appreciation for beneficial effects of UV on plants (Schreiner et al. 2012; Wargent et al. 2011) has caused ecologists (as well as plant physiologists and horticulturalists) to re-examine and, in some cases reinterpret, plant responses to UV (Mazza et al. 2012; Wargent and Jordan 2013). The discovery and characterization of a specific UV-B photoreceptor (UVR8; Rizzini et al. 2011) and elucidation of other aspects of UV-B-signal transduction (Favory et al. 2009) has greatly increased our mechanistic understandings of the nature of UV perception and UV-induced photomorphogenesis (Jenkins 2014). This line of research has further prompted ecologists to examine how UVR8 interacts with other photoreceptors (e.g., cryptochromes and phytochromes) to mediate plant behavior and defense against pests and pathogens in natural settings (Mazza and Ballaré 2015). Increasingly, plant ecologists are recognizing that UV serves as a source of information for plants, which influences various aspects of their behavior and defense (Ballaré 2014; Barnes, Tobler, et al. 2015). Thus, these findings have expanded the field of plant photosensory ecology to include the study of UV as well as visible light signals.

Figure 4.1: Living and dead saguaro cacti (*Carnegiea gigantea*) plants in the Sonoran Desert, Arizona, USA. Solar UV radiation (280–400 nm) can influence the growth and development of living plants as well as the decomposition of dead plant material (litter). Photo by Steve Archer, University of Arizona, USA.

In addition to these molecular advances, research conducted by ecosystem ecologists has identified UV as an important driver in the decomposition of dead plant material (i.e., litter). While ecologists have known for some time that UV can influence decomposition (e.g., via effects on decomposing microbes and litter chemistry), the report by Austin and Vivanco (2006) was the first to convincingly demonstrate that UV could have a strong, positive effect on litter decomposition via the process of photodegradation. This study was conducted on grass litter in Patagonia, Argentina, and sparked further investigation by a number of other researchers to examine UV-driven photodegradation in arid and semi-arid ecosystems in North America, Africa and the Mediterranean region (e.g., Almagro et al. 2016; Brandt et al. 2010). More recent studies suggest that photodegradation interacts with microbial processes in ways to influence litter decomposition in moist as well as dry ecosystems (Austin and Vivanco 2006). Thus, it now clear that UV can play an integral ecological role throughout the life and death cycles of terrestrial plants (Fig. 4.1, Bornman et al. 2015).

At the present time, there is a renewed interest in the study of UV effects on plants and terrestrial ecosystems. No doubt this “mini-renaissance” has been fueled, at least in part, by the discovery of the UV-B photoreceptor and the heightened appreciation for the role that UV plays in governing litter decomposition and biogeochemistry. Advances in UV measurement and dosimetry (Aphalo et al. 2012), artificial UV lighting (LEDs; Wargent 2016) and field-portable instruments that enable ecologists to non-invasively measure UV protection in plants (Barnes, Flint, Ryel, et al. 2015) have also contributed to this renewal. The European Union-sponsored COST Action FA0906 ‘UV4Growth’ program has been instrumental in fostering the growth of UV plant research by sponsoring UV conferences, training sessions for students, and facilitating collaborative research among ecologists, plant physiologists, photobiologists and plant molecular biologists (Aphalo et al. 2015; Jansen et al. 2015). These activities have been crucial for the development of young ecologists who have little formal training in UV photobiology. This program has not only kept ecologists abreast of the latest findings in molecular biology but has also encouraged molecular biologists to address ecologically relevant questions. As a result of this COST program a new scientific society (International Society for Plant UV Research) has emerged that will continue to foster these cross cutting activities. These collaborations will no doubt lead to new insights into what role UV plays in influencing the fitness, distribution and abundance of

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plants in nature. And who knows, perhaps someday soon all ecology textbooks will include UV as an important ecological factor in the life (and death) of plants.

Acknowledgements

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Research Profiles

Lars Olof Björn
UV4Plants Association's first honorary member

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Figure 5.1: Lars Olof Björn at the last UV4Growth COST Action meeting at Bled, Slovenia. The meeting where the idea of forming a scientific association was born.

Introduction

Some time ago I intended to send Lars Olof some specific questions by e-mail to assemble an interview in a questions and answers fashion. However, I first discussed with him through e-mail the broad idea I had for the interview. Next day I received a well organized text matching what I had in mind. So Lars Olof's text became the core of this profile. This article also includes sections contributed by researchers who have collaborated with Lars Olof in one way or another. The year 2016 has been a special year for Lars Olof: he turned 80, and formally retired from his professorship at South China Normal University (Guangdong). Of course, this does not mean that Lars Olof has retired from experimental research or lost the curiosity that has been the motor behind his career: he continues doing experiments at home, and actively discusses his ideas with researchers like me and continues to make some of his encyclopedic knowledge available to a wider audience through popular articles and books. This year, at our Association's General Meeting in Pécs, Hungary, Lars Olof was named by unanimous vote the first honorary member of the UV4Plants Association.

Lars Olof's life story *by Lars Olof Björn*

I was born on Gotland in the middle of the Baltic in 1936 and stayed there almost until the end of WW2. The family moved around, so I studied in different schools until I started at Lund university in 1954. After my basic studies I worked as an assistant in the laboratory of Daniel I. Arnon at Berkeley 1957–1958. This financed half-time studies in biochemistry and other subjects at Berkeley, after which I married in 1959 (see Fig. 5.2 for the time line, and Fig. 5.3 for the locations mentioned in the text.).

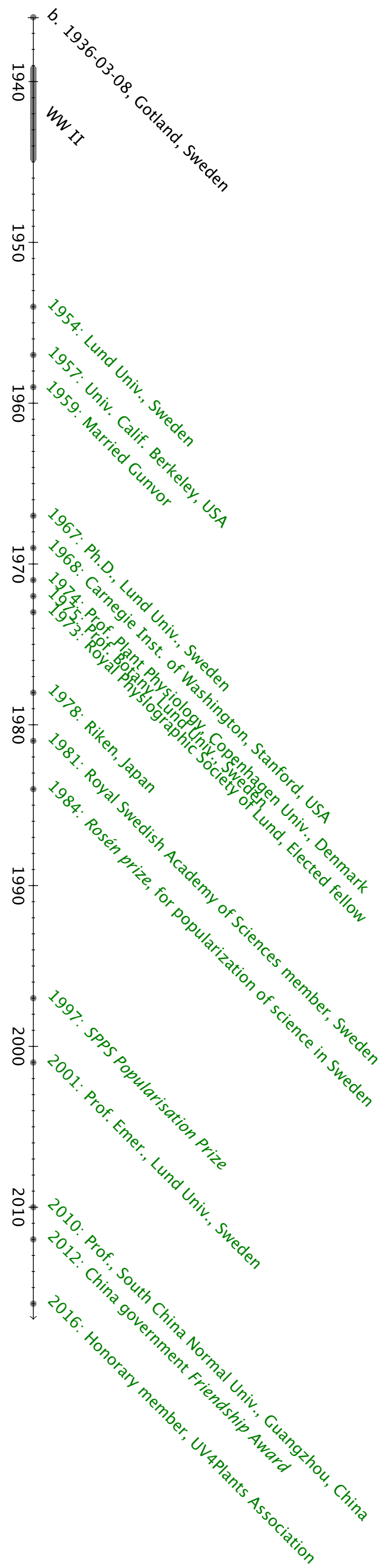

Figure 5.2: Time line for Lars Olof Björn's life story.

Before I went to America I had done a small photobiology project under the supervision of Hemming Virgin, later professor of plant physiology in Göteborg. He had moved away during my stay in America, but I wanted to continue with photosynthesis, which I had become fascinated with in Arnon's laboratory. However, my professor (Hans Burström) said that after Arnon had discovered photophosphorylation in chloroplasts and Calvin (also at Berkeley) had clarified the path of carbon, there was no more important photosynthesis work to be done, so instead he suggested something else. While I had been away, a guest researcher from Poland, Z. Hejnowicz, had studied protochlorophyll in root tips. I could continue with this. Hejnowicz had written something about it in Nature, which I could find myself, said the professor. This was all the guidance I got, as far as I remember, and I worked for several years without any real progress. But I had good talks with Per Halldal (later professor of plant physiology in Umeå and finally in Oslo), who was for some time there, and I think that my situation was really saved by a Japanese guest researcher, Yonezo Suzuki, who was studying isolated wheat roots growing in culture. He had made the observation, a little aside from his real topic, that these wheat roots formed chlorophyll when exposed to blue light, but not when exposed to red light only. I found this interesting, and it became the starting-point for my doctoral dissertation ("The effect of light on the development of root plastids"), which was completed in 1967. So I really had a slow start, taking almost 9 years for my doctoral work, although I was away for 18 months of military service and studied mathematics and physics on the side (read the theory in the evenings during military service, and did the lab work later during summer vacations).

Before I finally completed my Ph.D. I also had an interesting experience working as an assistant for Hans Burström's teacher. Henrik Lundegårdh. This very gifted man,

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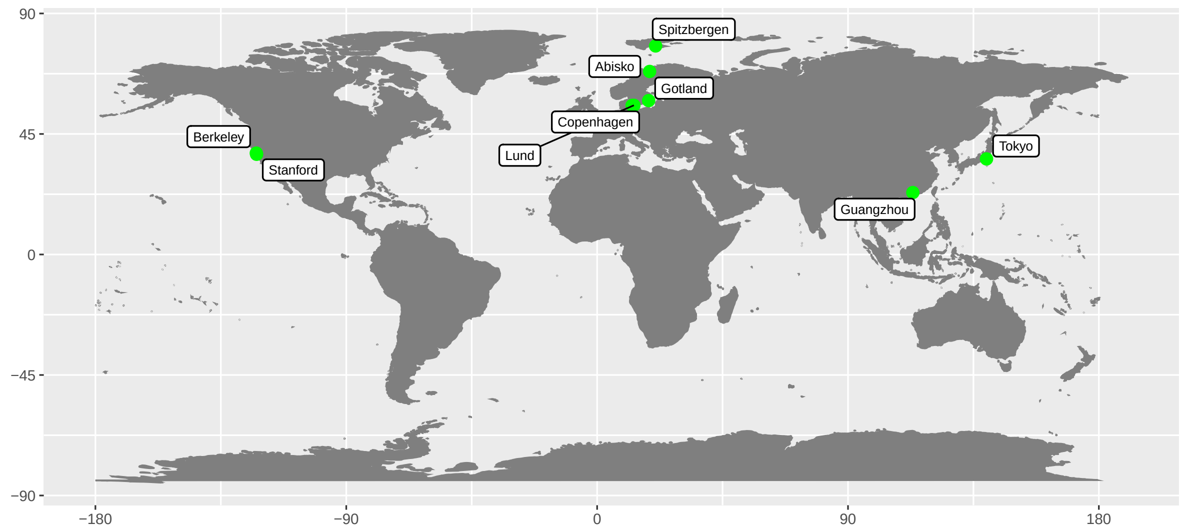

Figure 5.3: Important places in Lars Olof Björn's life.

thought of as the father of Swedish plant physiology as well as plant ecology, was like a professor from a fairy-tale. He had been professor at what is now the Swedish Agricultural University at Ultuna near Uppsala. But he did not like students or paperwork, so he quit and built his own laboratory at the coast. He had constructed the first "flame photometer" for agricultural use and developed a method for analyzing the mineral content of leaves in order to determine the nutritional status of plants, and had earned sufficient money from his patent to allow this "free lancing". He had enormous self-confidence, and when I arrived the first he said was "Burström could at least have sent a docent", but I think that he appreciated me later, and in fact I had to teach him some electronics, which did not seem to be his strong side. He had been a great designer of laboratory apparatus, and from scratch built a spectrophotometer for in-vivo measurements which people came from far away to study (during my time there a Frenchman (Gaston Ducet) who wanted to do spectroscopy on mitochondria). Lundegårdh was very afraid of radioactivity, and my main role was to measure photophosphorylation using ^{32}P. Initially I failed, and suspected the water quality, since the the water came from a metal water still. He did not believe me, but finally he took out a quartz double still from his storage, and after that the phosphorylation was no problem. I was not allowed into his house with the radioactivity, but worked in a shed outside. Since we could not agree on the interpretation of my results I did not appear as coauthor (the same result as for my work with Arnon).

After this, things went a little better. I soon went back to U.S.A. for half a year, this time to the Carnegie Institution of Washington at the Stanford campus. This was a very good time in my life, and I think that I did my best work there, by finding that a single molecule of a certain substance could influence the energy state of a large part of a chloroplast, corresponding to about hundred thousand chlorophyll molecules. Had not Mitchell already formulated his chemiosmotic theory, which I was unaware of, this would really have been great. The director, Stacy French, was very kind and helpful, and although he did not directly participate in the experiments and it was I who initiated the project, built the apparatus etc., in retrospect I regret that I did not include him as coauthor.

I was really interested only in science, so when back in Lund my good wife Gunvor kept us alive by working as a chemistry teacher and keeping a tight grip of our budget. (When economy and children later permitted, she got her own biology Ph.D.) I never thought of promotions or money or considered the fact that the docent position I had got was time-limited, but one day Hans Burström turned up in my room and said that a professorship in Copenhagen was open for application, and that I ought to apply. I think that this was the second piece of guidance that he gave me, and it was probably because it would look good if somebody from his lab would apply. He was not really interested in my work, neither did he believe, I think, that I would have a chance to get the post. But competition was not so strong, so I got it. Since my oldest child was already in school in Sweden, I chose to keep my home in Lund, and commuted daily to Denmark. It was rather hard, since there was no bridge in those days. I had to travel by car to Malmö, then boat to Copenhagen, then one bus, then transfer to another bus. I had to get up early and came home late.

The next year, however, Hans Burström retired, and I applied for and got his position.

Until then I had conducted much of my life in darkrooms, which was necessary for the study of the light processes that I was interested in. I continued with this for a total of about twenty years, with rather disparate studies of chlorophyll formation, photosynthesis, phytochrome and cyanobacterial pigments. Nothing of this can be said to be important research, but some of it gave me great pleasure and was intellectually stimulating. Especially I remember the pleasure I had in studying the geometry of the phytochrome molecule and the photoinduced rotation of its transition moment, by converting a spectrophotometer into an apparatus for measuring linear dichroism and developing from scratch the rather complex mathematics and computer programs. Gunvor and I had started to prepare for this during a stay in Kazuo Shibata's lab at "Riken" in Japan, and Gunvor had learned to purify phytochrome using instructions that I had got from Pill Soon Song in Texas. In later experiments I cooperated with Christer Sundqvist (later professor of plant physiology in Göteborg), who had learnt (during a stay at Carnegie) to immobilize phytochrome molecules by attaching them to Sepharose. The computers were primitive in those days, and we had to run the programs overnight. It was exciting to come in the morning and see if everything had worked as it should. Often there was some bug that had turned up late in the run. I think that the experiments were good, but they have had no lasting value since they were superseded by other methods.

After these ca. 20 years in darkrooms there came a change. I had started some simple experiments on effects of ultraviolet radiation on plants with Janet Bornman (later professor in succession in Denmark, New Zealand and Australia). Mats Sonesson, professor of plant ecology in Lund and director of the science academy's research station at Abisko in Lapland had heard of this, and urged me to come to Abisko and set up field experiments concerning UV effects there (Fig. 5.4). The reason was the concern that had started to emerge regarding the thinning of the ozone layer and the concomitant increase in ultraviolet radiation. I was happy to come back to Lapland. My mother was born there, and I had spent time there during my childhood and adolescence. So another 20 years followed, during which I and my wife spent part of the summers at Abisko, and not only did science, but combined science with pleasure and took many walks among the mountains. We also enjoyed meeting other kinds of people during these years. I wish to especially mention the very good doctoral student Ulf Johanson who helped to set up these experiments and worked with them during the coming years, and also helped to set up similar experiments on the island of Spitzbergen

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Figure 5.4: Lars Olof Björn in Abisko, Sweden, 1992. (P. J. Aphalo)

in the Arctic. I should also mention Terry Callaghan, who succeeded Mats Sonesson as director of the research station. There are not many who know the plant ecology of the Arctic nearly as well as Terry. Another Ph.D. student, Carola Gehrke played an important role in the early Abisko experiments.

But I also had students who were more interested in life in water than on land. When Nils Ekelund (later professor, first at the Mid-Sweden University, and later in Malmö) first turned up and wanted to start work for a Ph.D. I tried to coax him into the Abisko work, but he had scuba diving as a hobby and insisted that he preferred to study the effect of ultraviolet radiation on algae. To supervise his work I got very important help from Donat Häder, and Nils spent some time with him at Erlangen. Nils eventually got his own UV-effects students.

When I retired in 2001 my post was not renewed, but another one of my (and Winslow Briggs') former doctoral students of photobiology, Susanne Widell, had already been promoted to professor and took over the responsibility for plant physiology, which underwent a major change when all the different biology departments were reorganized to a single super-department of biology. For a few years I tried to become retired, but then gave up and accepted a half-time post as professor in China, which I had been invited to at the initiative of one of a former guest researcher in our lab, Shaoshan Li, who had since advanced in the hierarchy (Fig. 5.5). In China it is enough to be old to be honored, so I got medals both in Beijing and Canton (Guangdong), and was appointed honorary

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Figure 5.5: Ceremony of appointment as professor of South China Normal University, Guangdong. Lars Olof Björn and the president of South China Normal University, professor Liu.

citizen of Guangzhou. I kept this position for 6 years. I retired from it in May 2016 after having passed the 80 year limit, but am still doing some advising of Chinese doctoral students via e-mail. I am also continuing simple experiments at home, and working on a book on photosynthesis. Contrary to what my professor thought in 1958, there is much that had been discovered about photosynthesis since then.

I have not been as specialized as many others, and do not feel that I have any very deep knowledge about anything. I am rather a generalist. Occasionally I have diverged from the study of plants to bacteria, fungi, birds, vitamin D in human skin. My first biological fascination was insects, which I was introduced to by my father. Looking back I have been very lucky and lived, on the whole, a happy life without worries.

Looking back I am struck by the lack of correlation between what I consider good and mediocre among my publications, and the number of citations that they have got. For instance, what I consider myself as my best paper, the one from Carnegie (1971), has been cited only 41 times in 44 years, while a very simple article from 2009 has got 55 citations in 6 years. Perhaps a comfort for those who think that they have good papers which have not got their share of citations.

Questions (PJA) and answers (LOB)

Q How have human relations among researchers, the “sociology” of science, changed since you were yourself a PhD student until the present day? I would expect that both positive and negative changes have taken place, and maybe not as a continuous trend.

A I think that the main change that I have seen is increased cooperation and, to an even greater extent, increased co-authorship. When I started to publish I had in most cases only my own name on the publication, and we were at most 3 authors. Nowadays single-authored publications are a minority, perhaps reviews forming an exception.

Also, I think that it in general took a longer time than now to complete experimental work. And, of course carrying out calculations and drawing diagrams was more complicated before computers started to be in use.

Q My view is that most of the younger generation of biologists tend to think of equipment for measurements as something given, something totally outside their own field. Yourself, as well as myself, have in practice been keen to play with equipment, modify it, and adapt it from other fields, when we have needed to do measurements requiring equipment we could not afford or that was not available. Do you see a change about this type of attitude in recent decades? Does current university education discourage the willingness of young researchers to "tinker" with equipment?

A To some extent this is a consequence of the growth of molecular biology. Molecular biologists mostly use ready-made equipment. To some extent it is true also for biology in general, as more and more ready-made equipment has appeared on the market.

Q With recent cuts in public funding for research in many Western countries, in particular for non-applied research, do you think that China will become more competitive? Both in science itself, and commercially? Have you seen also a cultural change in the attitudes of Chinese researchers? And how does Chinese culture favour and/or hinder an independent and objective approach to research compared to Western culture?

A Yes, China is becoming more competitive, even if the Chinese economy recently has slowed down. I have noticed that more and more Chinese names appear among the authors in international journals, and in many cases the articles published by Chinese are very good. However, it is clear that not always all people listed as authors have really been involved in the research. And Chinese culture and education, with a tendency to regard authorities as infallible, is not optimal for science.

Q If you were nowadays starting a career as a researcher what field of research would you find the most interesting and exciting to pursue?

A When after basic studies I was to choose a topic for my doctoral thesis I said to my professor that I wished to continue with photosynthesis (I had already worked as assistant for Daniel Arnon in his studies on photophosphorylation for a year). But my professor said (in 1958) that there would be absolutely nothing more to discover about this process, so I ought to do something else.

I think that at that time my choice would have been good. And I think that photosynthesis is still an exciting field. Alternatives for me today, had I been young today, could have been the origin of life or some branch of microbiology. Or entomology. Insects were my first biological interest, and I still find them very interesting. Perhaps insect orientation, migration and navigation.

Contributed texts and illustrations

Janet Bornman

What first comes to mind is probably how well Lars Olof fits the descriptions of Peter Medawar's assessment in Pluto's Republic (Medawar 1982). Medawar described scientists as "people of very dissimilar temperament doing different things in different ways. Among scientists are collectors, classifiers and compulsive tidiers-up; many are detectives by temperament and many are explorers, some are artists and others artisan. There are poet scientists and philosopher scientists and even a few mystics". More specifically, Medawar also regarded the work of biologists as "very close to the frontier between bewilderment and understanding. Biology is complex, messy and richly various, like real life, it travels faster nowadays than physics or chemistry (which is just as well because it has much farther to go), and it travels nearer to the ground". Lars Olof certainly unravelled many facets of biology for both scientists and non-scientists.

As for the 'richly various' component of biology, Lars Olof brought scientists from all over the globe to work on projects. Looking back, this opened up the world of science and rewarding people contacts. As a member of the committee that awards the annual Nobel Prize in a variety of disciplines, he also helped in arranging seminar visits to Lund University by some of the Nobel laureates who were either on their way to or from the prize-giving event. I was privileged to meet Paul Crutzen in this way who shared the Nobel Prize in Chemistry with Mario Molina and Sherwood Rowland in 1995 for their work on the formation and degradation of ozone.

Lars Olof can always be relied upon to act or respond quickly. A good example was when I walked into his office at the Department of Plant Physiology one day in 1980 and asked about the possibility of starting a PhD. I walked out a few minutes later with a UV-B radiation project. Although technically a photobiology project, I spent the next 4 years in dark or green light as so many photobiologists do. There were, however, several lighter moments such as in the middle of 'serious' PhD work on UV radiation on plants, I was asked to put some cooled frogs into special spectrophotometer cuvettes to measure, if I recall correctly, their light reflectance.

An excerpt from Lars Olof's poetic recollections of the above, read out at my PhD dissertation:

One day she gave me a ring on the phone,
And she told me "I'm feeling so very alone,
I'm so bored in my house.
Please take me as a student!
I'm truly tidy and prudent.
I will work hard and fast
and will leave as the last
when the work-day is past"

I answered after a while that " I will,
because I have a gap in my spectrum to fill.
I have people working from far-red to blue,
but now I need you,
because I want ta
use more energetic quanta"

Éva Hideg

"Well, that's what I think. But be sure to ask Lars Olof as well." -- ever helpful colleagues usually ended scientific discussions with these words at Lund University's Department of Plant Physiology during my visit in the 90's.

One just had to find Lars Olof. He spent a lot of time at the department; it was just the heisenbergian problem of location. He could be downstairs in the greenhouse, having to check some plants urgently, despite the "insecticide-do-not-enter" sign posted by the gardener. Ducking under the ladder placed there to block the entrance and bearing the above sign was simple enough. Or maybe he was in his dark room, fiddling with the ultrasensitive photon counter that he built and placed inside a wooden box rather than the usual metallic one. By this simple and ingenious design he prevented the plethora of problems arising from electrostatic interactions between metal shielding and wiring that other labs spent millions of yen to solve (usually by building another metal box around the first one). He could also be upstairs in his office, with the huge pyramid pile of journals, reprints and manuscripts which stayed on top of the large conference table defying physics and were kept in an organised chaos only Lars Olof mastered. Or anywhere between basement and top floor, stopping by at another department, seeing old friends or former students, curious how their experiments were going. Soon enough, you heard him. Never using the elevator, just sort

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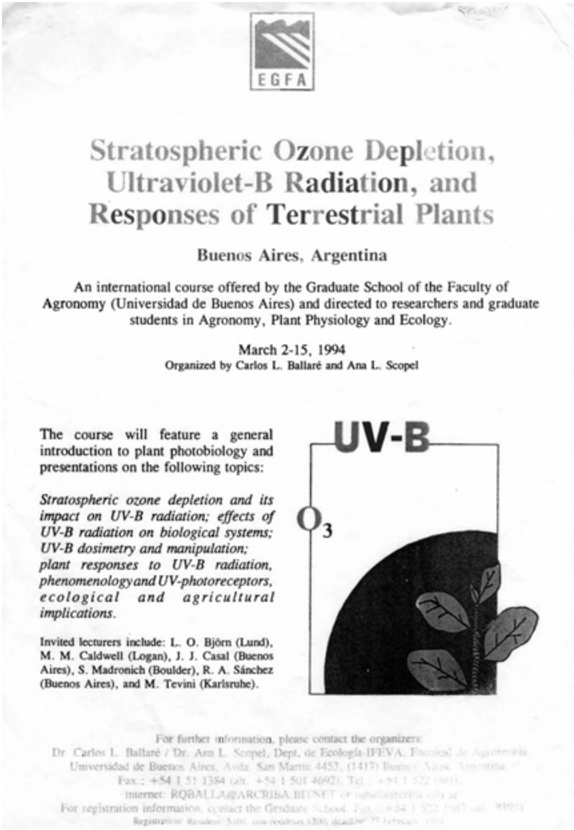
of running and jumping downstairs, skipping stairs. Bump, bump, bump. As far as he knew, that was the only way of coming downstairs, although sometimes he may have felt that there really was another way, as he advised people against following suit.

Having found him, Lars Olof was always ready to discuss. At the department in, or during the too short period we spent in the same lab in Japan, later on when we met at conferences or simply via emails. I'm feeling incredibly and undeservedly lucky that I know him in person. He may disappoint people expecting the unquestionable dogmatic truth from a professor, as his wisdom usually comes in questions. Because Lars Olof makes you think and think again from another viewpoint. And when you are about to leave feeling satisfied and enlightened, he lets you go saying that he may be wrong, so be sure to think about it some more. Although unanimously liked by students, his questions at PhD viva were often dreaded. This is because unlike teachers who formulate exam-like questions on such occasions, Lars Olof tends to ask you ones he does not know how to answer. Well, at least not at that particular moment. Later on, he'll ask himself again for sure.

Curiosity, Humor, Kindness, Sharing, Wisdom -- five key words to summarize. Thank you, Lars Olof.

Pedro J. Aphalo

Many of us owe Prof. Lars Olof Björn a lot. He generously used and uses time to help others, both within the scientific community and outside it. He is also generous in sharing new ideas and encouraging and helping others explore new avenues. I cannot imagine other researchers thinking of him as a competitor. I met Lars Olof for the first time in Buenos Aires in March 1994, and we have kept in contact since then. I remember three events that were particularly significant for me: being invited by Lars Olof to give a seminar in Lund, Lars Olof turning up in a visit to Joensuu in 1996 with a big wooden box, and listening to his talk at the SPPS meeting in Uppsala. We met for the first time when a UNEP meeting was held in Buenos Aires, and Carlos Ballaré organized an intensive course on UV-B photobiology taking advantage of the presence of visitors willing to teach (Fig. 5.6). On one evening we had dinner at the Larreta Restaurant in the Belgrano neighbourhood. Janet Bornman, Carlos Ballaré, Ana Scopel, my wife Tarja Lehto and our daughter Rosa (in a pram) also participated in the dinner.


EGFA

Stratospheric Ozone Depletion, Ultraviolet-B Radiation, and Responses of Terrestrial Plants

Buenos Aires, Argentina

An international course offered by the Graduate School of the Faculty of Agronomy (Universidad de Buenos Aires) and directed to researchers and graduate students in Agronomy, Plant Physiology and Ecology.

March 2-15, 1994
Organized by Carlos L. Ballaré and Ana L. Scopel

The course will feature a general introduction to plant photobiology and presentations on the following topics:

Stratospheric ozone depletion and its impact on UV-B radiation; effects of UV-B radiation on biological systems; UV-B dosimetry and manipulation; plant responses to UV-B radiation, phenomenology and UV-photoreceptors, ecological and agricultural implications.

Invited lecturers include: L. O. Björn (Lund), M. M. Caldwell (Logan), J. J. Casal (Buenos Aires), S. Madronich (Boulder), R. A. Sánchez (Buenos Aires), and M. Tevini (Karlsruhe).

For further information, please contact the organizers:
Dr. Carlos L. Ballaré / Dr. Ana L. Scopel, Dept. de Ecología-IFEVA, Facultad de Agronomía
Universidad de Buenos Aires, Avda. San Martín 4453, (1417) Buenos Aires, Argentina
Fax.: +54 1 51 1384 (alt. +54 1 501 4692), Tel.: [illegible]
internet: RQBALLA@ARCRIBA.BITNET or [illegible]
For registration information, contact the Graduate School: Fax [illegible]
Registration: [illegible]

Figure 5.6: Announcement of the UV-B course at the Graduate School of the Faculty of Agronomy, University of Buenos Aires, 1994.

I probably mentioned before a planned visit by Lars Olof's to Joensuu (Eastern Finland) my worries about the calibration of our then new Macam spectroradiameter. Because of this, he just turned up with his Deuterium calibration lamp as an additional piece of luggage weighing several kilograms, carrying it all the way from Lund.

Soon after, in 1997, I listened to Lars Olof give a plenary talk at the SPPS congress in Ultuna (Uppsala), Sweden. The talk was linked to a prize Lars Olof had received from SPPS for his efforts in the popularization of science. That talk was eye-opening for me, not so much from the scientific knowledge point of view but rather from what drives Lars Olof into doing scientific research. At a time when tough competition among researchers was becoming the norm, an approach I never felt comfortable with, Lars Olof's talk provided me with a successful alternative model that I could comfortably subscribe to. And this spirit was always present in him, willing to help with a student-exchange EU application with Latin-American partners that I was coordinating, being the opponent of Tania de la Rosa, the first PhD student I supervised, and of course being a key contributor to the *Beyond the Visible* handbook, both scientifically and with his encouragement and example of getting things done.

I have also had the pleasure of meeting Gunvor and Tesla. I have enjoyed the hospitality of Gunvor and Lars Olof, both in Lund and in Abisko, and learnt something new almost each time I have chatted (in person or remotely) with Lars Olof. Thank you, Lars Olof, and let's keep doing things together!

Highlighted publications (PJA)

It is difficult to make a selection of publications to showcase Lars Olof Björn's broad interests, except for the book edited and partly written by him: *Photobiology: the science of light and life* (Björn 2015), which is already at its third edition. When selecting the remaining publications I include in this section I did not look at impact factors. I think what best describes Lars Olof's publications are "lateral thinking" and "ingenuity". *Lateral thinking* is solving problems through an indirect and creative approach, using reasoning that is not immediately obvious and involving ideas that may not be obtainable by using only traditional step-by-step logic. Ingenuity is the quality of being clever, original, and inventive. I limit myself to scientific publications and textbooks, as the huge contribution of Lars Olof to the popularization of science in Sweden is described by Åke Strid in a separate article on page 29.

Books

Light and Life (Björn 1977).

Environmental UV Photobiology (Young et al. 1993).

Beyond the Visible: A handbook of best practice in plant UV photobiology (Aphalo et al. 2012).

Photobiology: the science of light and life (Björn 2015) and two earlier editions.

Broad perspective

"Technical discussion I - underwater light measurement and light absorption by algae" (Björn et al. 1996).

"Viability of lichen photobionts after passing through the digestive tract of a land snail" (Fröberg et al. 2001).

"Vitamin D synthesis may be independent of skin pigmentation only with UV of short wavelength" (Björn 2010).

"Comment on "Catalytic Efficiency of a Photoenzyme-An Adaptation to Natural Light Conditions" by J. Popp et al." (Björn 2013).

"Thermal emissivity of avian eggshells" (Björn et al. 2016).

Ingenious methods

"Measurement of light gradients and spectral regime in plant tissue with a fiber optic probe" (Vogelmann and Björn 1984).

"Estimation of fluence rate from irradiance measurements with a cosine-corrected sensor" (Björn 1995b).

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Figure 5.7: Some of the books edited and/or written by Lars Olof Björn

"Effect of back reactions in the S-cycle on photosynthesis in very weak light" (Björn 1995a).

"Time-resolved studies of light propagation in *Crassula* and *Phaseolus* leaves" (Johansson et al. 1999).

Demonstrations used in teaching

"Teaching about photosynthesis with simple equipment: analysis of light-induced changes in fluorescence and reflectance of plant leaves" (Björn and Li 2013).

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Research Profiles

Knowledge for knowledge's sake: Personal thoughts on Professor Lars Olof Björn's impact on plant UV photobiology and on Swedish popular science over the last three decades (at least)

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Swedish Plant UV Photobiology and collaborations with Lars Olof

The national Plant UV Photobiology scene in Sweden is small and has been so for at least the last 25 to 30 years, with maximally five research groups active in the field at the same time. Lars Olof has of course been its star performer and the inspiration for all the groups, and Lund University has been the intellectual epicentre of these efforts.

Two of the research groups (headed by Nils G A Ekelund, now at Malmö University, and Sten-Åke Wängberg at University of Gothenburg) centred their research on UV and aquatic photosynthetic organisms. Nils in his early career collaborated with Lars Olof at Lund University, where he also did his PhD. Janet Bornman and her group performed top class UV research on e.g. plant physiology, photosynthesis, and global issues. This includes her instrumental contribution to the United Nations Environment Programme (UNEP) manifested in the quadrennial assessments on environmental effects of ozone depletion and its interactions with climate change. Finally, myself concentrated on molecular and biochemical aspects of UV-B effects and responses in model species such as pea and *Arabidopsis*. Given the disparate interests of the Swedish Photobiology research groups, any clustering of knowledge within plant UV photobiology never occurred in our country. Instead, there has been considerably more international collaboration for these groups than collaborations nationally.

The exception to this was of course Lars Olof. As the omnipotent intellectual he is, he masters all these parts of photobiology and more. He contributed a lot to the science of some of the groups and published research papers with all above mentioned scientists, with the possible exception for Sten-Åke. Lars Olof of course also participated heavily in the work for UNEP, especially in the early years.

Thus, a few fruitful collaborations between my own research group and the groups at Lund University resulted and I am holding the days of joint efforts in fond memory. In the late 90's and early 00's my group was interested both in UV-B-dependent tissue-specific expression of defence genes and tissue-specific DNA damage and the correlation between the two at the signalling level. The pea variety Argenteum has leaves with an epidermal cell layer that can easily be peeled off if the plants have been grown under the right conditions. Together with the

Lund groups and the group of Profs. Tadashi Kumagai and Jun Hidema at Tohoku University, Japan, we studied both DNA damage and expression of defence genes in mesophyll and epidermal tissue after UV-B exposure in acclimated and non-acclimated Argenteum plants (Kalbin et al. 2001). Using this set-up we were able to decouple DNA damage from induction of expression of general defence genes, i.e. concluding that DNA damage itself was not a molecular regulator of transcription of these genes.

A few years later, when Lars Olof suffered from ill health for several months, he had a young scientist from China, Dr. Shaoshan Li, on the way in from South China Normal University in Guangzhou for the second time as a visiting scientist to Lund. Lars Olof thought he might not be able to fully support Shaoshan the way he wanted to and therefore contacted me as a back-up. Thus, Shaoshan came to us in Örebro and our collaboration with him and Lars Olof became fruitful. Several papers resulted from Shaoshan's visit. In the most important of these studies Lars Olof was personally involved to a large extent. We had designed a UV irradiation device in Örebro based on a high power deuterium lamp and narrow UV band pass filters with half-band widths of 10 nm. Using this equipment we studied UV-regulation of four different genes. Two of these were primarily regulated with a peak at 290 nm and below (with little or no regulation at 300 nm), whereas the other two were regulated at 300 nm and above (with little or no regulation at 290 nm) (Kalbina et al. 2008), pointing to two different mechanisms of UV absorption. The statistical analysis posed some problems and we could again rely on Lars Olof. Through his contacts at Lund University we got expert help. The late Jan Lanke, then Professor emeritus of biostatistics, solved the problems in discussion with Lars Olof and myself.

The collaboration on these issues also meant that Irina Kalbina, now a lecturer in my research group and the first author of the second study above, got to know Lars Olof and his wife Gunvor well on a personal level. Irina had the opportunity to indulge in Lars Olof's and Gunvor's hospitality in their home, to savour Gunvor's soups and discuss common interests such as science, literature, music, history, and the philosophy of life. Irina also got the opportunity to discuss hands on scientific issues with Lars Olof during the course of the collaboration and when writing her doctoral thesis, the viva of which was very kindly visited by Lars Olof and Gunvor.

After retirement Lars Olof took up a part time Professorship at Shaoshan's Institute at South China Normal University where he stayed for about a dozen years and helped out to build UV Photobiology research.

Lars Olof as a role model in fundamental research

In my mind, Lars Olof personifies the virtues of some scientific qualities that are becoming more and more scarce among fellow researchers in todays's quest for external funding and high citation rates, and frustration of showing enough signs of applied research and stakeholder interactions in our annual reports. These virtues are: i) a great interest in science in the wide sense, not only in the natural sciences and in technology, or in his own projects, but also in the projects of his fellow peers, and of scientific efforts in medicine, in the humanities and in the social sciences; ii) the lust of sharing scientific insights and interesting details to the general public and to students in particular; iii) a humble approach to his own persona and a curiousness of what his peers are up to and what they have learnt.

Thus, Lars Olof is a true representative of the very best of what fundamental research stands for …or as this type of science has lately been termed by anglosaxan research policy makers: 'Blue Skies Research'. However, who would be a better guide to what hidden optical secrets 'Blue Skies' could re-

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veal than Lars Olof himself?

Lars Olof and Swedish popular science

Lars Olof is one of the most important figures when it comes to popularizing science in his home country. He is a regular writer in "Forskning & Framsteg" (approximate translation: "Research & Progress"), Sweden's most important popular science magazine. He is the one most published individual in this magazine, with more than 120 shorter or longer articles to his name (as found on the journal's webpage). He also has his own blog on the same web site (http://fof.se/person/lars-olof-bjorn), where he writes in Swedish about many aspects of science and in a way that is easily understood by the general public. For his outstanding contribution, he did in 1984 receive the Rosén prize, the chief prize for popularization of science in Sweden. Lars Olof also writes about science in a popular way on his web page at Lund University (http://www.cob.lu.se/photobiol/), in both Swedish and English. During his time at South China Normal University he also had a web page in Chinese and he gave a TEDx talk (in English with Chinese subtitles). A Lars Olof 'classic' is his instruction for building "The poor man's spectroradiometer" (http://www.cob.lu.se/photobiol/poor.pdf) using a cheap light source (a light bulb or a laser pointer), a DVD disc, a digital camera, a few pieces of wood and metal, a personal computer, and the Image J software. Since 1981 Lars Olof is a fellow of the Swedish Academy of Science, in the Class for Biosciences as member no. 1222.

With this I will end, thanking Lars Olof for his inspiration, his ample contribution to science, and wish him an active and fruitful future.

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Editorial board reviewed article.

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Methods
Solar spectrum through the wavelet lens

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Measurements of spectral irradiance, which are used to describe the solar spectrum, can be viewed as signals made up of rough and smooth components. Wavelet analysis (Percival and Walden 2000), which we present in this article, allows one to extract these components. Wavelet analysis was developed in the 1980's and 90's (Daubechies 1992; Mallat 1998) and is primarily used as a tool for exploring time series and image data, in fields ranging from physics to finance. It breaks up the signal into components associated with scale and time (in the context of spectral irradiance, with scale and wavelength), where small scales correspond to the rough part of the signal, while large scales correspond to the smooth. This gives rise to the so-called Multi-Resolution Decomposition (equation (7.1) below). In the current paper we emphasize the smoothing application of the methodology, though we discuss the decomposition for all scales, and explain how to perform and interpret wavelet analysis of spectral irradiance data.

Why would we want to smooth out the spectral irradiance? Smoothing is not needed when calculating typical indicators of light quality such as red:far-red or UVB:PAR photon ratios as these are based on integrals of spectral irradiance over particular wavelength bands. However, if we want to compare entire spectra (functions) collected under different experimental conditions rather than integrals (numbers), such a prerequisite step might be necessary. This is precisely the case with functional data analysis (Horváth and Kokoszka 2012; Ramsay and Silverman 2005). Within this framework signals are treated as functions, but they have to be smooth at the outset. A comparison of functions, in our case (smoothed) spectral irradiance measurements, can then be facilitated by, for example, functional multi-way ANOVA (Albertos and Bande 2010).

Let $X = [X_{\lambda_1}, X_{\lambda_2}, \dots, X_{\lambda_n}]$ represent the signal (e.g., one of the measurements from the top-right panel of Figure 7.1 or the average of those measurements depicted in the top-left, given on a grid of equi-spaced wavelengths λ_1, $\lambda_2, \dots, \lambda_n$, with the sampling interval $\Delta\lambda = \lambda_i - \lambda_{i-1}$), then the Multi-Resolution Decomposition, MRD, states that

$$X = D_1 + D_2 + \dots + D_{J_0} + S_{J_0}, \qquad (7.1)$$

where $D_j = [D_{j,\lambda_1}, D_{j,\lambda_2}, \dots, D_{j,\lambda_n}]$, $1 \leq j \leq J_0$ and $S_{J_0} = [S_{J_0,\lambda_1}, S_{J_0,\lambda_2}, \dots, S_{J_0,\lambda_n}]$. '$D$' stands for Detail (there are several of them), while 'S' stands for Smooth (there is only one smooth). The number of components on the right-hand side of equation (7.1), governed by the positive integer J_0 ($J_0 \leq J = \lfloor \log_2(n) \rfloor$), depends on the task in hand. In the example of Figure 7.1 we chose $J_0 = 3$ because for such J_0 we were able to separate the smooth part of the measurement of the spectral irradiance (bottom-left panel of Figure 7.1 for the average and bottom-right for the individual ones) from the rough one captured by the details D_1, D_2 and D_3 (middle panels of Figure 7.1, left for the average and right for the individual). Had we have stopped at $J_0 = 2$,

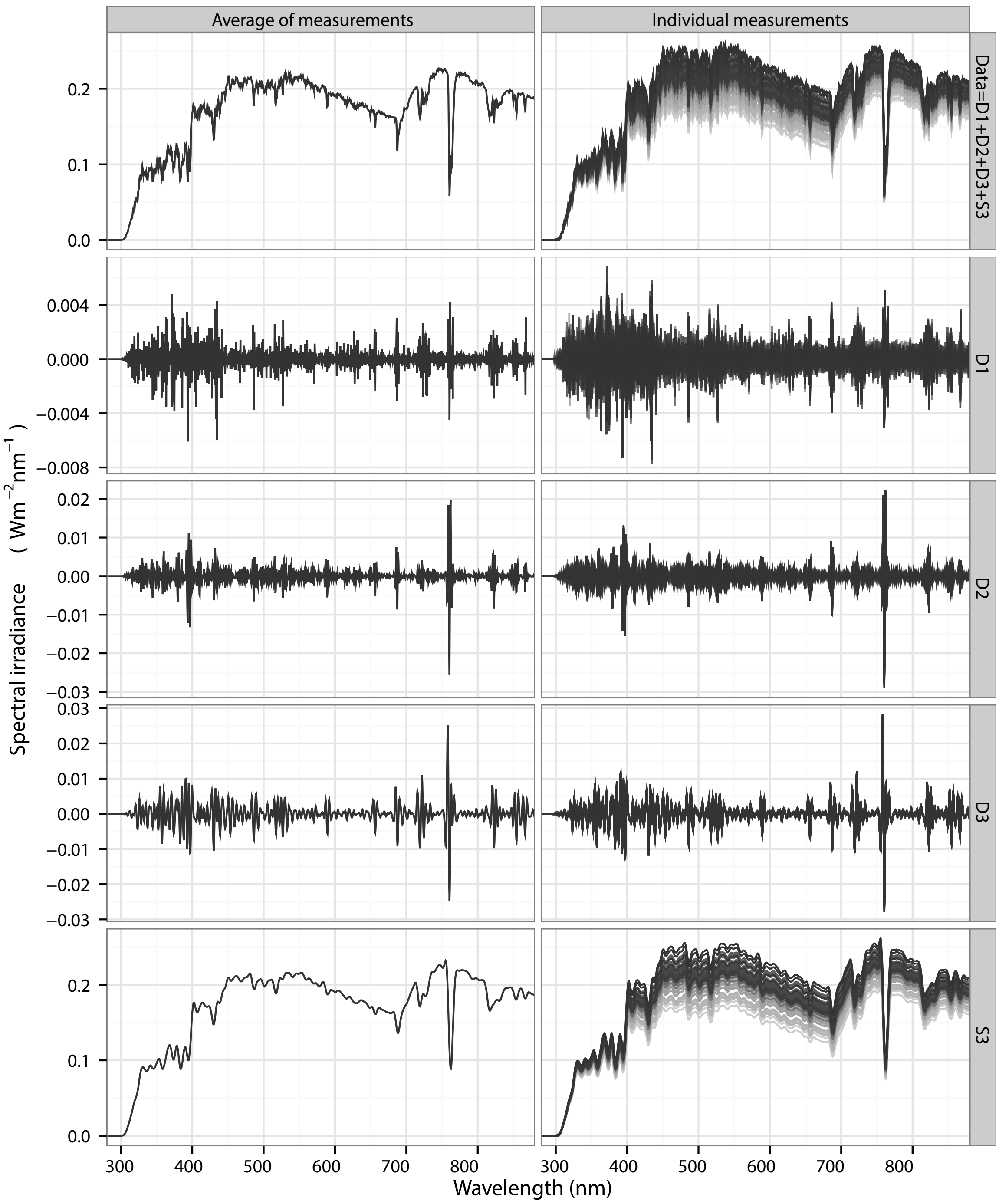

Figure 7.1: *Top:* spectral irradiance: average of measurements in the left and individual measurements in the right. *Middle and bottom:* Elements of the Multi-Resolution Decomposition (D_1, D_2, D_3, S_3) of the spectral irradiance based on wavelet analysis. Data collected with an array spectrometer (*Maya2000Pro*, Ocean Optics, 100 measurements over 50 seconds) on the 22.05.2015 around solar noon at Lammi Biological Station, Lammi, Finland (61°03'N, 25°02'E) in a leaf semi-shade position of a *Betula pendula* stand.

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our final element of the decomposition, S_2, would have consisted of the sum of the two bottom rows of Figure 7.1, and as such would have been affected by the roughness coming from D_3. The elements of the details and of the smooth, which essentially reflect variations in local averages of the signal, are interpreted as follows: D_{j,λ_i} is associated with the change/difference in weighted averages of X over two adjacent wavelength bands of width $2^{j-1}\Delta\lambda$, one band ending at λ_i and the other starting at λ_i ($2^{j-1}\Delta\lambda$ is referred to as scale); S_{J_0,λ_i} is associated with averages of X over wavelength bands of width $\geq 2^{J_0}\Delta\lambda$.

Let's have a closer look at the elements of the decomposition (left panels for the average of measurements and right panels for the individual measurements, at wavelengths (in nm) $\lambda_1 = 280, \lambda_2 = 280.5, \ldots, \lambda_n = 880$, with $\Delta\lambda = 0.5$). The measurements, recorded at nearly equi-spaced wavelengths with gaps from 0.43 to 0.48 nm, were interpolated to equi-spaced wavelengths (constant, left-continuous interpolation). The smooth (bottom panels), tracks its respective signal very well and indeed is smoother than the data itself. Hence smoothing of the spectral irradiance is achieved by dropping all the elements of the decomposition apart from S_3. What about the details? First of all, their y-ranges are much smaller than the y-range of the corresponding smooth. Detail D_1 (capturing the changes in the signal over the smallest wavelength band of size $2^{j-1}\Delta\lambda = 2^0\Delta\lambda$, hence 0.5 nm) based on the averaged measurements exhibits less variation compared to the details D_1 for the individual measurements, because we essentially averaged out the coarse part of the data in the former. Also, since in the right panels the different measurements (and their MRDs) are shown in different shades of grey, from lighter to darker, we notice that the details are largely consistent between the measurements (darker shades are superimposed on the lighter shades), which is not the case for the smooth. If we compare D_2 and D_3 in the left panels to those in the right ones, we also observe a high degree of overlap, hence the impact of averaging the measurements on these two components is far smaller than on D_1.

Several spikes in D_1, D_2 and D_3 around wavelengths (in nm) 370, 390, 430, 490, and 760 can be spotted. They imply that the changes in local averages of the spectral irradiance over scales of, respectively, 0.5, 1, 2 nm ($= 2^{j-1}\Delta\lambda$ for $j = 1, 2, 3$) at those λ_i's were much bigger compared to others. The inspection of the signal corroborates this, but it would be harder to detect such features without the wavelet lens. Another interesting quality of the MRD is an apparent increase in the variability of D_1 for wavelengths of up to 450 nm (it is also possible to perform a test of homogeneity of variance for the wavelet coefficients from which the details are derived). This suggests that the changes in local averages over scales of 0.5 nm at the beginning of the spectrum are much higher than for the remaining part. We leave the physical interpretation of these phenomena to the reader.

One can obtain MRD and plot it in `R` in three lines of code thanks to the package `wmtsa`, which accompanies the book of (Percival and Walden 2000). We demonstrate it below with the `sunspots` data set included in that package. Of course we skipped the technical details of the analysis, e.g., the choice of a particular wavelet transform, wavelet filter, handling boundary conditions, and refer the reader to Section 5.11 of (Percival and Walden 2000) for the details. The data and the `R` code (exceeding three lines) utilized in the current paper are available upon request.

```
#install.packages("wmtsa")
library(wmtsa)
x.modwt<-wavMODWT(x=sunspots,
                  wavelet="s8",
                  n.levels=3)
x.MRD<-wavMRD(x.modwt)
plot(x.MRD)
```

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Tutorial

SIOX plugin in ImageJ: area measurement made easy

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Introduction

Area measurement is frequently needed in research. ImageJ is a powerful free image processor for this purpose and resolves the measurement in a simple way. However, the advantage of the countless functions from ImageJ may be seen as confusing by beginners. One frequently asked question about area measurement is how to select the region of the image to be quantified, as a good area estimate depends on the accurate *segmentation* the object of interest from its background.

Segmentation can be defined as finding the boundary between the object of interest and its background. To do the segmentation manually for a leaf whose area is to be measured, one needs to trace its contour. Here I discuss how to automate this process through image processing.

ImageJ (Schneider et al. 2012) is a powerful image processor, focusing on scientific imaging analyses. It is free open source, written in Java language, which offers the convenience and possibilities for developments of plugins for different purposes. In 2009, development of ImageJ2 was initiated. Fiji (Schindelin et al. 2012) is a software distribution that consists in ImageJ2 (Schindelin et al. 2015) with many additional plugins preinstalled. ImageJ2 is mostly compatible with ImageJ1 supporting the use of both old and new plugins.

In this short guide, two alternative methods for object segmentation are described: a) automated extraction with plugin SIOX (Simple Interactive Object Extraction) and b) manual threshold selection. Sample images are shown in original form and after the different processing steps so as to facilitate a better understanding for these two methods. This article can also serve as an introduction to the subject when the intention is to use automated methods like that provided by the ImageJ plugin Rosette Tracker (Vylder et al. 2012).

How to start

Area measurements such as the calculations of leaf area or infected area are often needed in biological research. Typically, this calculation is fulfilled by 4 steps: 1. Take a photograph that includes the target object on an uncluttered and highly contrasting background; 2. Define the scaling: the conversion factor between pixels (the actual units that are counted in the photograph) into a unit that has actual meaning to the user (e.g. millimetres); 3. Segment the object from the background; 4. Count the pixels in the segmented object and convert this count into the quantity of interest.

These steps indicate some key elements of a successful calculation: a good photograph, a good segmentation and a good conversion. Once you have obtained a good photograph of the object, ImageJ then will do the other jobs.

Some years ago, I wrote a blog post, introducing this area calculation using ImageJ1 (Schneider et al. 2012). By answering questions from readers, I have learnt that the most difficult steps for those new to area quantification in digital images is to learn how to capture a good image and how to segment the object of interest as cleanly as possible. Here in this short guide, I introduce the steps of using a segmentation plugin called SIOX (Simple Interactive Object Extraction), compare it with the method of manually setting a threshold, and suggest some tips for photographing suitable images. This guide will help you understand better the methods used for image-area segmentation and consequently make you aware of what image characteristics help in the analysis. In addition you will better understand how both the physical setup and illumination used for photographing together with correct camera settings can help to obtain easy-to-analyze images.

Fiji (2.0.0) was used in this guide. Although we used ImageJ under Apple's OSX, it can be also used under UNIX, Linux and MS-Windows. Being free software, it is widely available. Visit (`http://imagej.net/Citing`) for information on how to cite ImageJ and plugins. Fiji can be downloaded from `https://fiji.sc/`.

SIOX

This section describes step by step how to use the SIOX plugin using a photograph of an Arabidopsis rosette as example. Fig. 8.1 shows the image in ImageJ at key steps in the processing. In the instructions below, *italicized* texts indicates menu selections in ImageJ.

A1 Import image (of an Arabidopsis rosette in this example). *File > Open* or drag the image into Fiji window.

A2 Set scale (Figure 8.1a). Select straight line tool on tool bar. Drag a line along one side of the red square in the image. *Analyze > Set Scale*. Known Distance is the length you dragged which is 3 cm. Tick "Global" for applying this scale to all the images generated from the sample image.

A3 Segmentation (Figure 8.1b,c,d). *Plugins > Segmentation > SIOX:Simple Interactive Object Extraction*. Use Rectangular/Oval/Polygon/Freehand tool to select a small area on the leaf area to be marked as known as Foreground. *Press Segment. Create Mask.*

A4 Calculation. *Analyze > Analyze Particles > Display Results/Summary*.

Manual threshold

B1 See A1

B2 See A2

B3 Split channels (Figure 8.2a,b,c). *Image > Colour > Split Channels*. This step can sometimes be skipped, e.g. when the contrast between object and background is high.

B4 Threshold (Figure 8.2d). Choose Blue channel. *Image > Adjust > Threshold*. Click freehand selection tool and select the rosette area.

B5 Calculation. *Analyze > Analyze Particles > Display Results/Summary*

Achieving a better result

Scale

The red cube in the sample image is the scale to convert pixel of the image into the unit for the area measurement which is centimetre in our example. Many factors in photographing can distort the shape and size and sharpness of the reference scale. For instance, the depth of image or the distortion by the camera lens. To keep it simple, the object used

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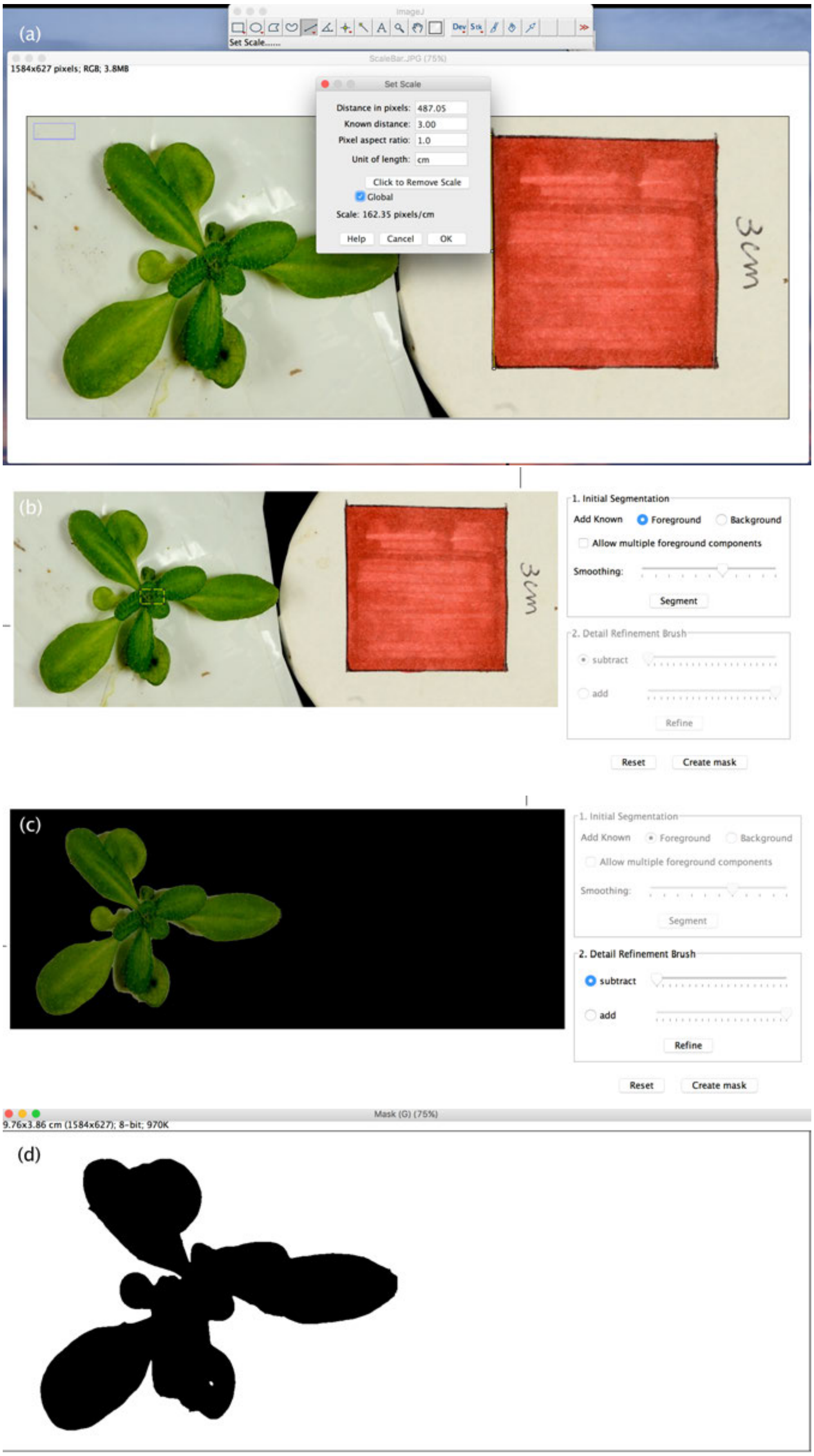

Figure 8.1: The steps of segmentation using SIOX: a) set scale; b) set foreground; c) refine the selection; d) the result of segmentation.

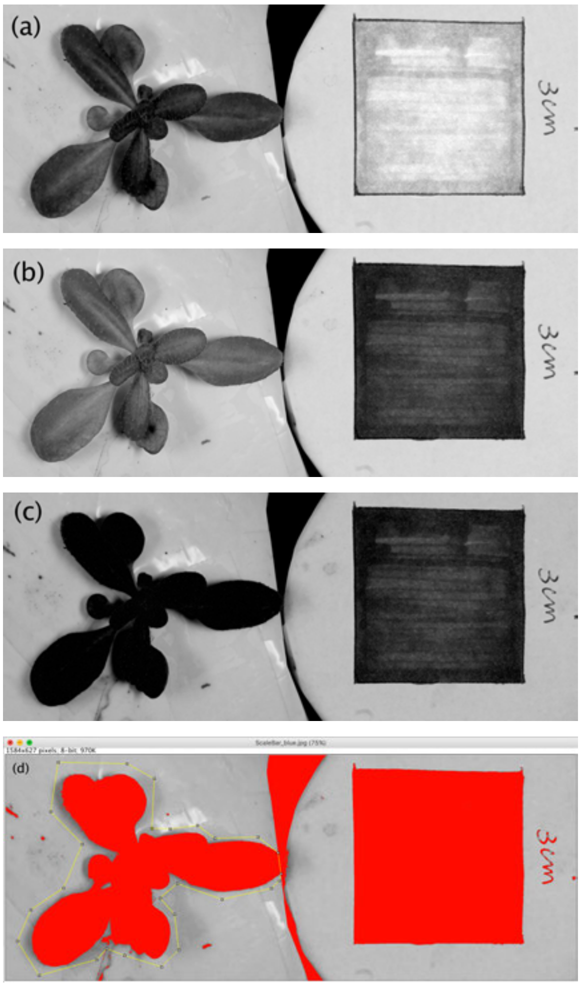

Figure 8.2: Split colour channels and threshold from same image of an Arabidopsis rosette as in Fig. 8.1: a) red channel; b) green channel; c) blue channel; d) the blue channel after applying a threshold, with the selected are highlighted in red.

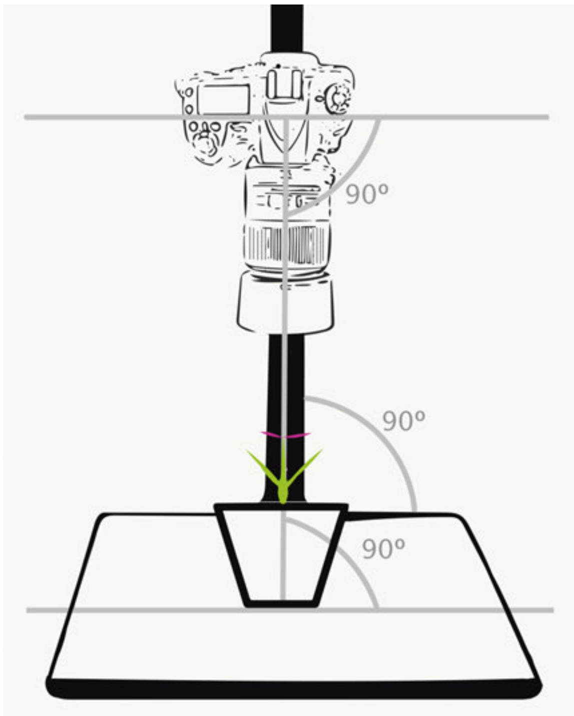

Figure 8.3: Drawing of a copy stand, with three angles that must be kept exactly at 90° marked.

as a reference scale should be located at the same distance and position from the camera as the target object. In other words, the two of them should be at the same vertical distance to the camera, and the reference parallel to the sensor or film plane of the camera. A copy stand is essential in many senses. It helps to stabilize the camera and strictly controls the level of the camera (Figure 8.3). Rarely leaves will be laying flat on the ground, so what is estimated with the methods described here is area of the leaves or rosette projected onto a reference plane. It also follows from this that some leaves or parts of the leaves in an intact plant will be nearer the camera than others. This source of uncertainty is usually tolerable for rosettes, but not for plants with stems. This problem does not affect individual leaves scanned or photographed laying on a flat surface.

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Colour channels

Images taken with colour digital camera consist in three separate channels of red, green and blue (RGB) sensor readings that when displayed or printed trick the human eye to see something similar to the photographed object or scene. In other words, normally the colors are mixed by our human brain. One way of obtaining a grayscale image is to display the luminosity values for a single color channel (see Figures 8.2 and 8.4). Technically, if we combine the three images of corresponding to the red, green and blue channels (Figs. 8.2b,c,d), we can reconstruct the original colour image of the rosette (Fig 8.2a). Splitting the colour channels doesn't change the pixel resolution of the image. Thus, the scale we defined in step A2 is valid for all the images derived from the same original image of the rosette (Fig. 8.2a). Thresholding can only be applied to grayscale images. That is why we have to split the channels (or alternatively merge them) first. The easiest segmentation through a threshold is to classify pixels into two output categories of black and white (i.e. convert a scale with many different luminance levels, or tones of grey, into a binary scale by use of a luminance level threshold at at chosen position along the grey scale). For the example image, I choose the blue channel because it is the channel with largest difference in luminosity between the rosette and the background. Other images may require the segmentation of one of the other channels.

Single channel threshold is ideal if the objects have large differences in color between the areas to be segmented. This is the case in the image of tulips taken under room light with a DSLR (Digital single-lens reflex) camera (Figure 8.4). The red flowers and green leaves have high luminosity (look white) in the red and green channels, respectively, while in the blue channel they cannot be distinguished. After splitting the three colour channels into separate greyscale images, the channels suit-

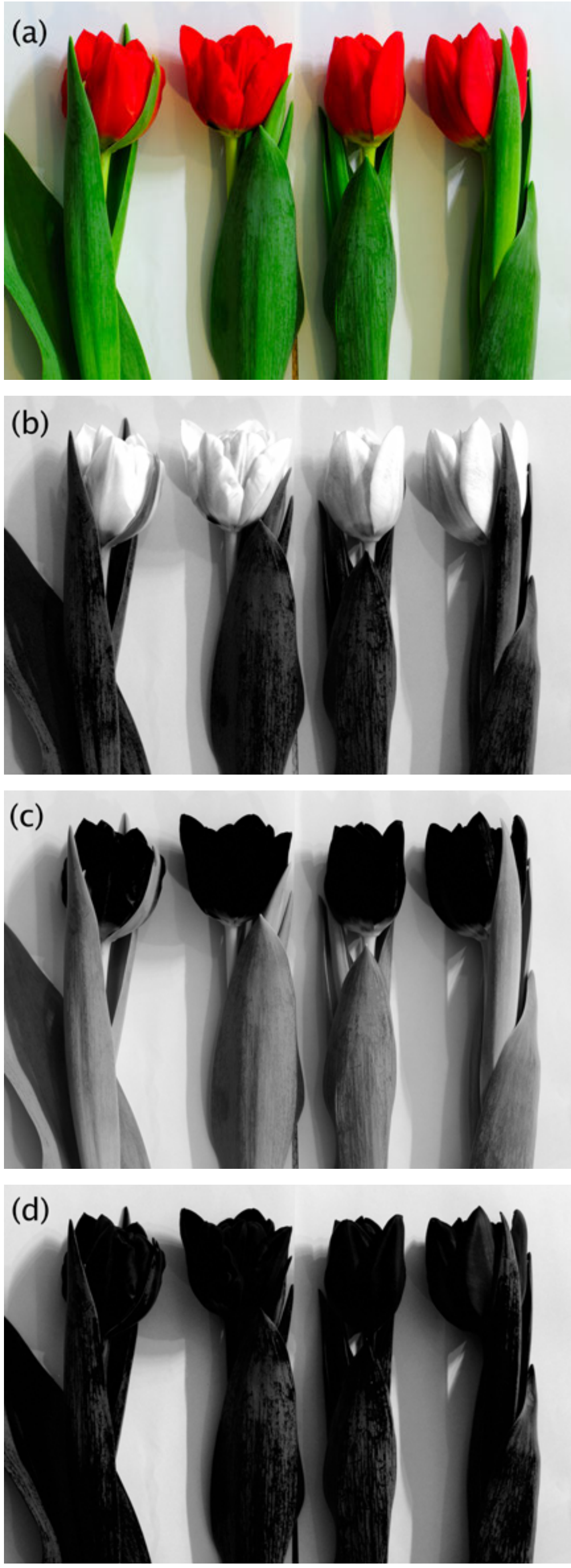

Figure 8.4: A digital image of tulips and its three colour channels: a) the original picture; b) the red channel; c) the green channel; d) the blue channel.

Figure 8.5: Digital image in UVA region of a dandelion (*Taraxacum* spp.) flower. Light source: 365 nm from LEDs; camera: E-M1, Olympus, Japan, converted to “full-spectrum” by DSLR AstroTEC, Engen, Germany; filter: U-filter, Baader Planetarium, Mammendorf, Germany; objective: “accidental” UV transmitting Hannimex 35mm f/3.5 No. 13368)

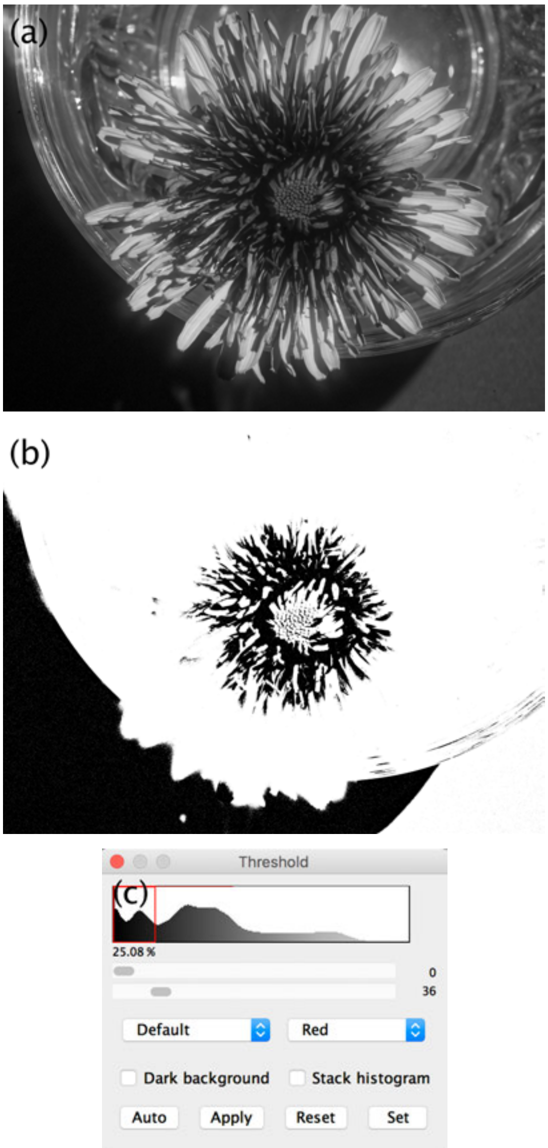

Figure 8.6: Colour channel and the result of threshold: a) Red channel of Figure 8.5; b) threshold of a); the setting of the threshold.

able for measuring flower and leaf areas are easily identified.

The example images shown above are easy to segment into areas of interest. Sometimes, we cannot obtain images that are as good as we would wish. Choosing a threshold manually is also useful for some objects, but the estimates obtained are more subjective. A photograph obtained under UVA illumination is used as example (Figure 8.5).

The dark area at the centre of the flower, visible only under UVA illumination, is of interest as it is visible to insects such bees even if not to humans. The luminosity of the different color channels in the absence of visible light is only the result of their different sensitivities to UV radiation rather than their designed differences in sensitivity to visible colours. The weak colour visible in the image is “false” as it is unrelated to human color vision. However, segmenting this area with the SIOX plugin is almost impossible because there is little difference in color. In contrast, thresholding on the separated colour channels returns very good results as there is a difference in luminosity. However, one should

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Table 8.1: Dark areas for dandelion flower. Selection tool *Oval* was used for selecting the area of interest. Under the tool icon, *x* and *y* indicate the center location of the oval area on the image; *w* and *h* indicate the width and hight of the oval that determine the oval area. To ensure the same location and the same size of the selected area in each channel, the parameters of x, y, w and h used were exactly the same. The dark area is expressed both as number of pixels, and as a percent of the selected area.

Image channel	Dark pixels (number)	Dark area (%)
blue	2032379	48
green	1378071	36
red	1416709	40

bear in mind that the size of the selected dark area will depend on the value chosen for the threshold and on the channel used. Figure 8.6 shows an example of thresholding on the red channel. In this image it is very clear that thresholding also selects a large section of the background. Before quantification, the area of interest at the center of the flower must the isolated with a mask drawn by hand. Drawing the mask is easy, as the white area separating the center of the flower from the background is very wide.

With the threshold set similarly for each single channel image the area estimates vary (Table 8.1). The area estimate for the blue channel is larger for than the other two. This is most likely due to differences in spectral sensitivity within the UVA region of the three channels of the camera's image detector. In Table 8.1 the areas are expressed in pixels as there was no size reference available. One could estimate the total area of the inflorescence and express the dark area as a ratio. We leave this as an exercise for the reader to try (The images are provided as supplementary information for readers to practice on.)

Further reading

This article gives a simple introduction to the most basic method of area estimation. The process of area segmentation can be automated within ImageJ and used to measure growth and other temporal changes in plants. The Rosette Tracker plugin (Vylder et al. 2012), available at `http://telin.ugent.be/~jdvylder/RosetteTracker/` together with its documentation provides the next step in sophistication when using time lapse imaging. A recent comparison of methods shows that consistency of quantification is not easy to achieve (Scharr et al. 2015), highlighting the need for careful protocol design and use. The ultimate in cost as well as throughput are automated plant phenotyping systems. Other plugins for ImageJ allow different approaches to the quantification and measurement of different biological structures at scales ranging from subcellular to aerial images. There is a lot more to explore, and a good way is to read both scientific publications and less formal technical reports. You can read the essay at `http://alvyray.com/Memos/CG/Microsoft/6_pixel.pdf` if you would like to understand more about pixels (or voxels). For further information on ImageJ you can read tips on its use at `http://imagej.net/Category:Techniques`. For a simple, modern and accurate account of technical (and artistic) aspects of digital photography you can read the two volumes *Learning to Photograph* (Banek and Banek 2013a; Banek and Banek 2013b).

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The editors.

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Training event report
Radiative transfer theory and modelling with libRadtran

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The ability to model the light environment using radiative transfer theory is a vital tool for scientists studying the radiation environment. libRadtran (Emde et al. 2016; Mayer et al. 2015) allows physicists and atmospheric scientists to compute spectral irradiance in the solar and thermal regions from 120 nm–100,000 nm, and to calculate radiative forcing due to different atmospheric components. It is also a useful tool for plant scientists wishing to study the effect of changes in spectral composition on plant responses at the leaf and canopy scale.

The doctoral program in plant sciences (DPPS) from the University of Helsinki sponsored me to attend the libRadtran workshop organised by the Finnish Meteorological Institute and CanSEE research group. The workshop was given by Arve Kylling from the Norwegian Institute for Air Research, one of the early pioneers and co-creators of the program libRadtran. Arve Kylling has a strong reputation and has published extensively on the methods to accurately-measure and model UV radiation in the Earth's atmosphere, and the influence that the Earth's atmosphere has on UV radiation. The libRadtran program provides a library for radiative transfer modelling, and includes functions for the calculation of solar and thermal radiation in the Earth's atmosphere. First developed in the 1980's, it still remains as open access software, freely available for any scientists wishing to utilise it.

At the core of libRadtran is the radiative transfer model uvspec, which describes energy transfer in the form of electromagnetic radiation. Radiative transfer models calculate how extraterrestrial solar radiation is altered by its path through the atmosphere. These models use extraterrestrial solar radiation as the starting point. Radiance is a distribution function, and defines the radiation field, which is a function of position, direction, frequency and time. Radiance is expressed per unit solid angle and per unit surface, given in $W\,sr\,m^{-2}$. The propagation of electromagnetic energy is affected by processes such as absorption and scattering. Absorption implies the 'death' of a photon, whereby a field of particles removes the incident energy from the photon, and converts this energy into a different form. Scattering is a change in the direction of a photon's propagation. Both molecules (Rayleigh scattering) and particles (aerosols, clouds, Mie scattering) scatter radiation. Irradiance, as opposed to radiance, is the measure of radiation striking a defined area of surface, and changes according to the distance between the source and the target surface (Figure 9.1). Irradiance is given in the units $W\,m^{-2}$.

The Beer–Lambert–Bouguer law is incorporated into the model, and describes the absorption of radiation along the beam direction and scattering out from the beam direction. Calculation of the vertical variation in these properties is achieved by splitting the atmosphere into boundary layers, with each boundary layer having defined proper-

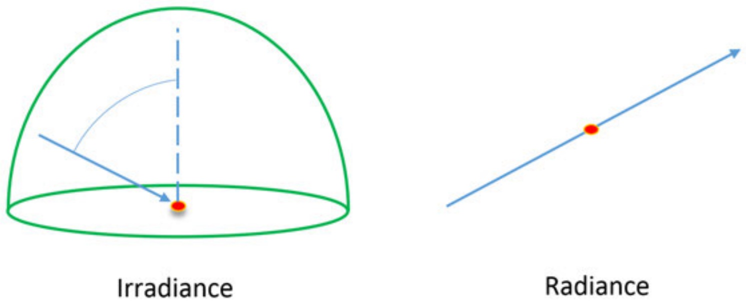

Figure 9.1: Visual representation of radiance and irradiance. The red circle represents the point at which a measurement is taken. Redrawn from (Lazarov 2011).

ties relating to its absorption and scattering. If the user wishes to model the irradiance under snow, rain, or even the ocean, then all of these can be treated as a boundary layer within libRadtran as well -- likewise under a plant canopy or horticultural greenhouse -- although these sort of boundaries were not quite what the model was envisaged for when it was developed. For instance, plant canopies can be considered a heterogeneous layer and thus the Beer-Lambert equation has often been modified to overcome this problem when modelling the light in forest understories. Modelling of within-canopy radiation transfer is commonly based on the Monsi-Saeki equation, which provides a simplified assumption that the canopy is composed of small horizontal leaves with a random distribution (Monsi et al. 1973). Using this method, empirical parameters such as the transmissibility of a leaf can be included in the model. For plant scientists using manipulative filter material to monitor the effects of UV or other regions of spectral composition, then the material can also be included as a boundary layer, and its attenuation properties can be defined to produce an accurate model of light below the filter. The final product of the uvspec model in libRadtran is the irradiance for every wavelength defined in the model.

There are some assumptions made in the model, which include that the atmosphere is one-dimensional and bounded at the top and bottom by horizontal plane surfaces (known as a plane-parallel atmosphere), the medium (e.g. atmospheric layer) does not change with time as the photon passes through it, that the frequency of the photon does not change as it interacts with the matter, and that the photons move in straight lines.

Once downloaded, the model can either be used through systems such as Cygwin (which allows a Linux-like interface to be operated from within Windows), and called from a Python or shell script, or via a graphical user interface. As mentioned, the core function in libRadtran is the uvspec radiative transfer model. This can be characterised into four different parts (Figure 9.2). Firstly, the atmospheric state or description is provided. The user then selects parameterisation values to convert the atmospheric state into optical properties, such as an extinction coefficient that describes the optical properties of a water cloud. These optical properties are then passed on to a radiative transfer equation (RTE) solver, which then produces an unprocessed spectral irradiance value.

A working directory has to be defined in Cygwin (or whatever operating system is being used to run libRadtran), and an input file is created which contains the parameter values and names of functions to use in the simulation for the uvspec model to read. This input file must be a text file format with a name tag '.inp'. Allowed input values are doc-

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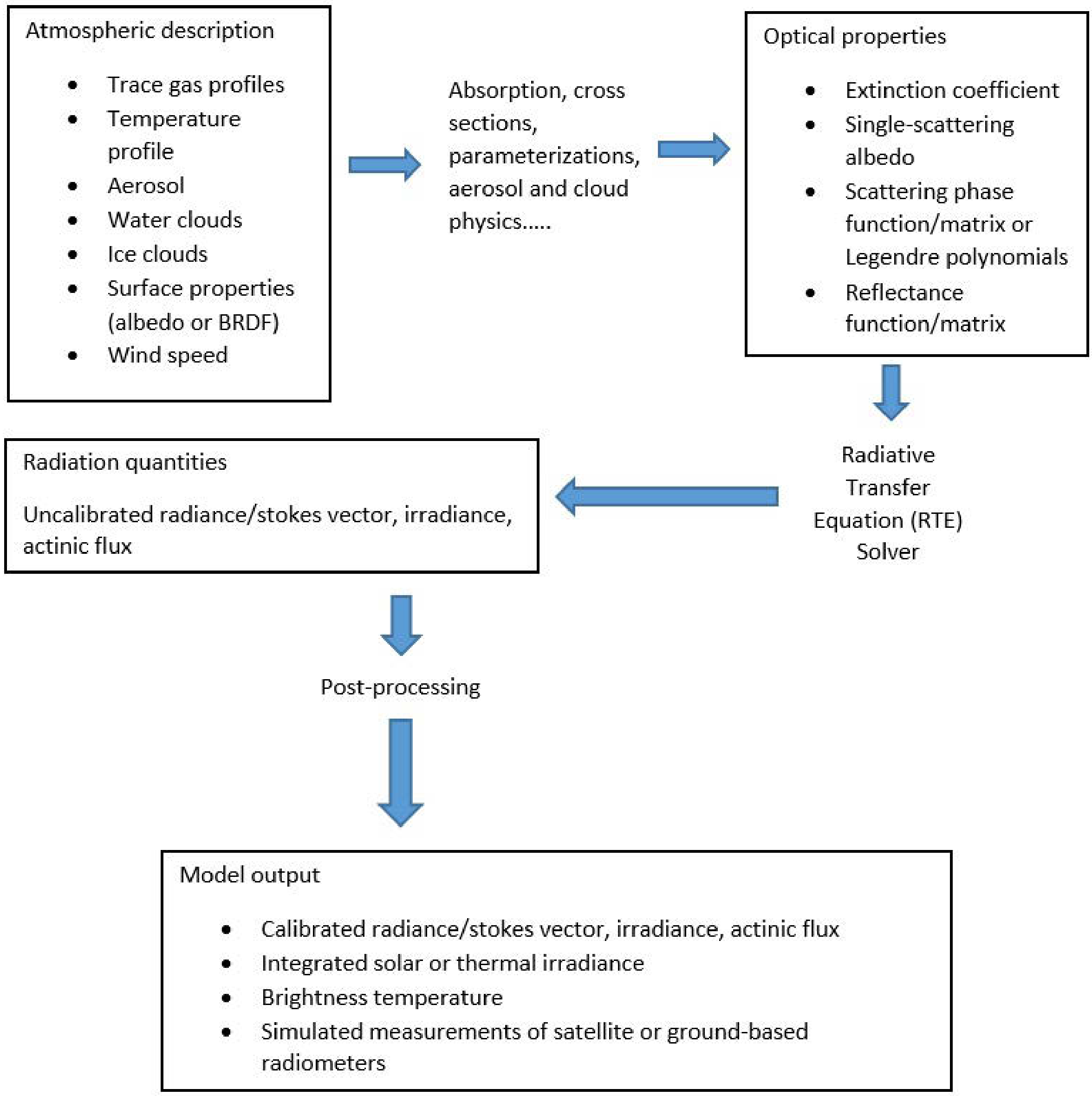

Figure 9.2: Structure of the uvspec radiative transfer model. Redrawn from (Emde et al. 2016).

umented in the functions, as well as example '.inp' files for different types of calculations which are available from the libRadtran website. There are several key features that allow the user to simulate the irradiance at any location on the Earth's surface, for any day of the year. The user can do this by referring to and editing the input file for the model. The surface type, altitude, zenith angle, day of the year, thickness of ozone column in Dobson units and the wavelength range can all be defined here within the input file. In addition, there are more advanced features for those wishing to adjust the number of beam directions used (a compromise between computation speed and accuracy), as well as clouds and their optical depth.

An output file is then saved into the same working directory. There are typically seven columns in the file describing irradiances and actinic fluxes (Figure 9.3). The first column lists the wavelength (nm) of light and the following six columns give the direct irradiance, diffuse downwards irradiance, diffuse upwards irradiance, and direct actinic flux (the total number of photons, or radiation, incident at any point from all directions), diffuse downward actinic flux and lastly diffuse upward actinic flux.

In this way, one can produce useful figures, such as Figure 9.4, which display the simulated spectral irradiance (calculated here as the sum of downward direct irradiance and downward diffuse irradiance) for a particular location on the Earth's surface at a particular point in time, or those such as 9.5, which display the modelled radiation components from Figure 9.3 for the same location and time. Following the steps provided for in uvspec, users are able to manipulate the conditions and input requirements to suit the scientific question at hand. As with most models, it is used most effectively alongside measured spectra to ensure accuracy. Usually the most difficult input to obtain is a good description of local cloud cover, which is crucial for any instantaneous or short term estimate.There are currently over 400 publications citing libRadtran, demonstrating its strong reputation amongst the scientific community.

libRadtran is but one of many radiative transfer models available for scientists to use. Another popular model with free access is the Tropospheric Ultraviolet and Visible (TUV) radiation model, which was developed by Sasha Madronich at the National Centre of Atmospheric Research, USA (Madronich et al. 1997). There are of course differences in how to use these different models. One advantage of the TUV model is that it provides a simplified "Quick TUV calculator" which one can access to obtain data simply through a web page online (http://cprm.acom.ucar.edu/Models/TUV/Interactive_TUV/). However, the TUV model operates over a shorter wavelength range: TUV can calculate between wavelengths of 150 nm--750 nm, whereas libRadtran can calculate any wavelength from 120 nm–100 000 nm.

There are still novel questions to be explored using the libRadtran model, particularly with regards to the response of plants to UV and other regions of light, and the possibility to model the spectral irradiance beneath forest and crop canopies, or even inside greenhouses. The libRadtran program provides an impressive toolbox allowing plant scientists to model the light environment in situations where measurements are not possible, or to be used as a predictive tool to model the light environment under future circumstances.

For more information on libRadtran, please visit www.libradtran.org

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Figure 9.3: Example rows from an output file from the uvspec model in libRadtran.

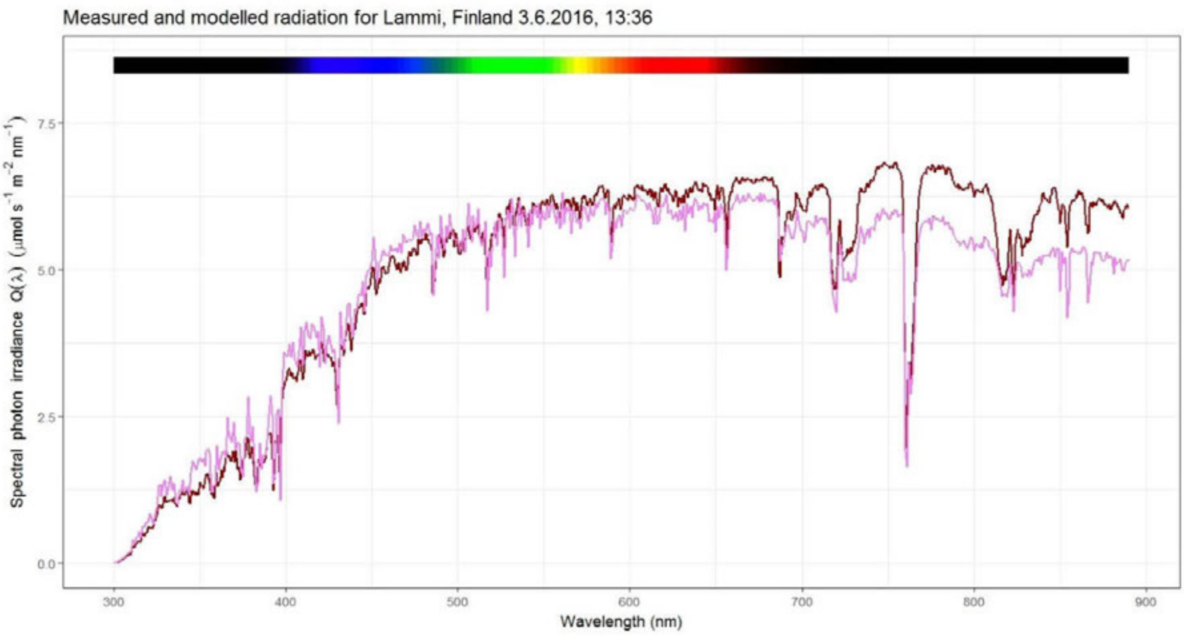

Figure 9.4: Plot of the spectral photon irradiance measured with a Maya2000 Pro array spectroradiometer on 4 June 2016 at solar noon (13:36) in an unshaded grass meadow adjacent to Lammi Biological Station (130 masl, 61°03'14.3"N 25°02'14.2"E). Measured solar irradiance (dark red) is compared with modelled solar irradiance (violet) using the uvspec model in libRadtran. Differences in the far-red region are likely due to nearby vegetation on the edge of the meadow, which whilst not shading, may have increased the amount of far-red light by selective reflection. The difference in blue and UV regions may have been the result of partial occlusion of the sky by adjacent vegetation or buidings.

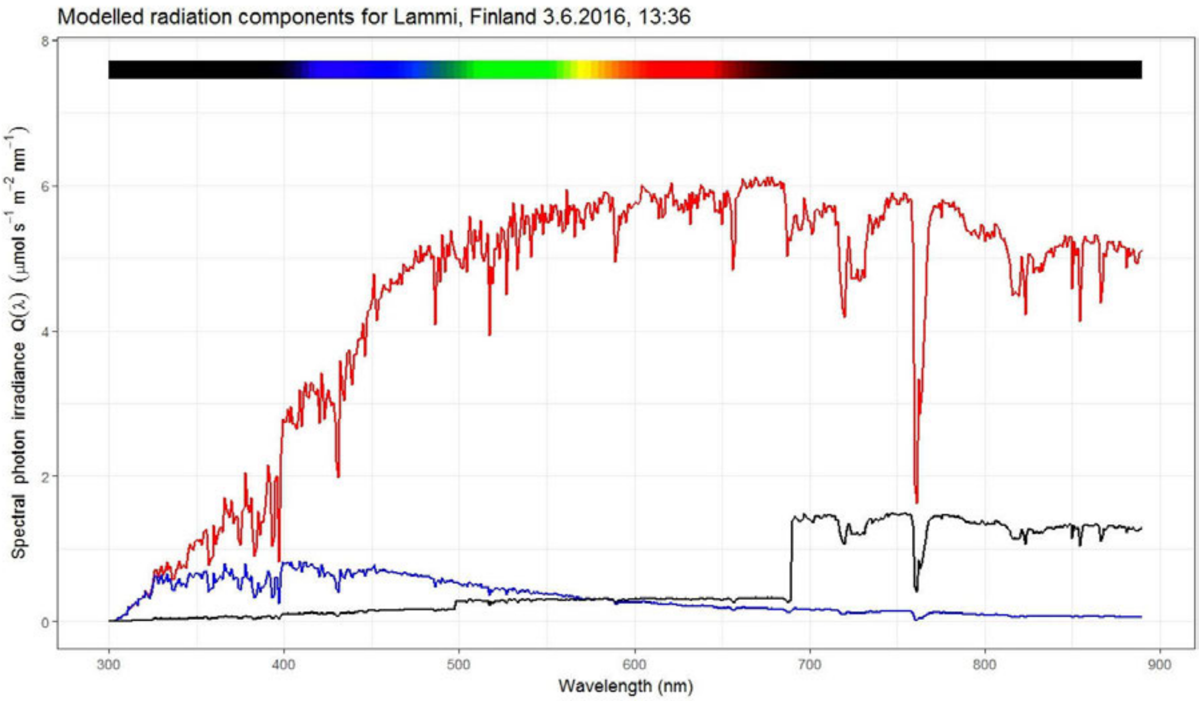

Figure 9.5: Plot of modelled direct spectral irradiance (red line), diffuse downward spectral irradiance (blue line), and diffuse upward spectral irradiance (black line) using the uvspec model in libRadtran. Modelled for the 4th June 2016 at solar noon (13:36) at Lammi Biological Station, Finland (130 masl, 61°03'14.3"N 25°02'14.2"E). The increase in diffuse upwards irradiance at 680nm is due to reflection by plant leaves in the far-red region.

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Book Review

OpenIntro Statistics, 3ed

by David M. Diez, Christopher D. Barr and Mine Çetinkaya-Rundel

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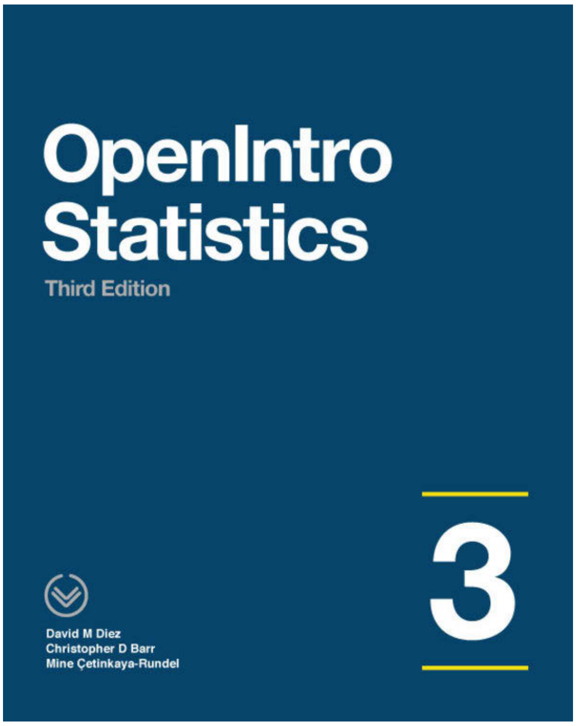
DOI: 10.19232/uv4pb.2016.2.90 © 2017 The Author, licensed under (CC BY-SA 3.0)



Before I start the actual review of the book authored by Diez et al. (2015), I will start by describing what are my expectations for a great introductory textbook of statistics.

1. Focus on principles, stressing how variations of the same ideas reappear across different data analysis methods.

2. Use of numerical exercises to demonstrate not so much the practical details of the use of methods, but rather the overall ideas behind statistics.

3. Very strongly emphasize the dangers of miss-interpreting and over-interpreting the results from tests of significance.

4. Keeping common sense and other criteria for relevance of results "on the table" when discussing and selecting examples and designing exercises.

5. Use of illustrations whenever they can help understanding.

6. Availability of supplementary materials for students and teachers.

7. Affordable and easy to acquire.

The OpenIntro book consists of eight chapters and two appendixes. The titles of the chapters follow a rather traditional path: 1. Introduction to data, 2. Probability, 3. Distributions of Random Variables, 4. Foundations for Inference, 5. Inference for numerical data, 6. Inference for categorical data, 7. Introduction to linear regression and 8. Multiple and logistic regression.

Throughout the book the focus of the discussion, although following a rather traditional organization, is different from other books in that the students are encouraged to get the grasp of the principles through experimentation or examples (see Fig. 1.13 from Diez et al. 2015, p. 18, reproduced in the appendix). Most exercises promote deep understanding, rather than simply exemplifying the mechanics of how a certain type of analysis is done. With examples, the approach used is new to me, but I expect it to be

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very effective: there are both "Examples" and "Guided practice" items within the main text. These are meant to be done while reading, and answers are provided for them. In addition to these, at the end of chapters, there are sets of traditional exercises for home work.

The book is clearly written by authors that are familiar with the usual mistakes with regards to statistical analysis in the published literature. Rarely nowadays do errors concern the calculations themselves. They are related mostly to misinterpretation of results of tests or model fits, either because of misunderstanding of assumptions or ignoring that they are not fulfilled. In my experience, students tend to first or only look at P-values, rather than starting by considering more broadly the practical or biological significance of the result. Many times, recurse to common sense, is forgotten. This is an area where the book excels. These points are highlighted and many examples used to demonstrate them, including figures (see Fig. 7.13 from Diez et al. 2015, p. 342, reproduced in the appendix).

The book is modern in that many numerical examples are used (417 examples and guided practice items, 350 end-of-chapter exercises), together with many illustrations (213 figures, not counting those in exercises). Example data sets are interesting, sometimes even very entertaining, and plots and diagrams are used as part of the analyses. This is my personal view, but it makes me happy that most of the illustrations are not "cartoons", but instead plots of actual example data.

Supplementary material includes video overviews linked directly from within the PDF file of the book. Data sets used in the book are available as an R package. Furthermore, the OpenIntro name comes from open-source, as both the PDF of the book and the LaTeXsource of the book are available for free! They are licensed under a Creative Commons BY-SA 3.0 license. This book may be downloaded as a free PDF at http://openintro.org. However, I encourage you to make a voluntary payment to help sustain this project, and an easy way of doing this is by buying a copy of the PDF at https://leanpub.com/openintro-statistics. A printed version is available through Amazon for a low price as a black and white paperback, and at a higher price as a full-colour hard cover book.

To summarize this review in a few words I can say that I wish I had studied statistics with a book like this, as I feel that many of the insights about data analysis that took me several years to acquire through practice and reading assorted literature have been distilled into this introductory statistics text book. This book is engaging and clearly written, and teaches what is really important, and includes enough information about modern approaches, such as re-sampling, to give a solid foundation for further study of modern statistical methods.

References

Diez, D. M., C. D. Barr, and M. Çetinkaya-Rundel (2015). *OpenIntro Statistics*. 3rd ed. OpenIntro, Inc. 436 pp. ISBN: 978-1943450053.

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Appendix: reproduced figures

Two figures out of the 213 in the book (Diez et al. 2015) are reproduced below under Creative Commons BY-SA license 3.0.

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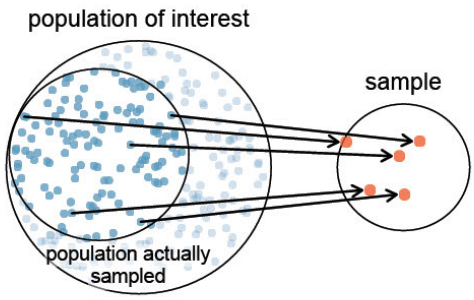

Figure 1.13: Due to the possibility of non-response, surveys studies may only reach a certain group within the population. It is difficult, and often times impossible, to completely fix this problem.

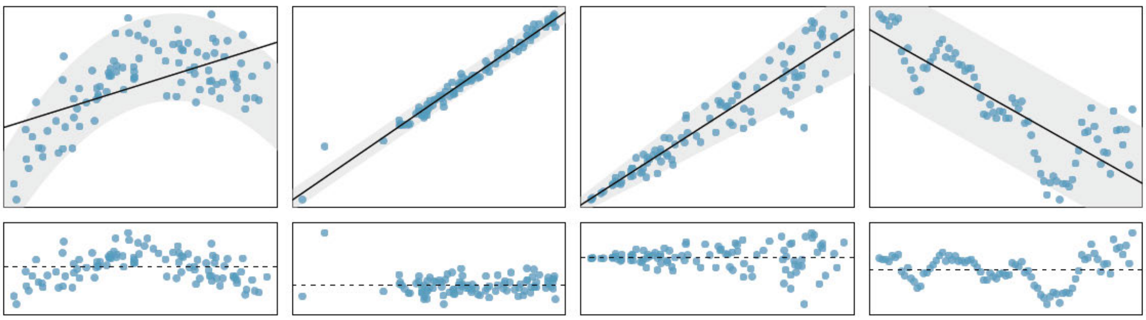

Figure 7.13: Four examples showing when the methods in this chapter are insufficient to apply to the data. In the left panel, a straight line does not fit the data. In the second panel, there are outliers; two points on the left are relatively distant from the rest of the data, and one of these points is very far away from the line. In the third panel, the variability of the data around the line increases with larger values of x. In the last panel, a time series data set is shown, where successive observations are highly correlated.

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UV4Plants

The International Association for Plant UV Research

Key aims of the UV4Plants international association are to

- promote and foster research-excellence and good practice in plant UV research through the organisation of innovative events in research, public engagement and education
- provide channels for members to inform the plant UV research community about relevant activities or events of common interest
- enhance the usefulness of plant UV research by facilitating the transfer of knowledge from academia to stakeholders and the general public
- initiate and foster stakeholder contacts as part of an agenda of product development
- liaise with scientific funding bodies to influence their research agenda
- develop with its members the benefits of membership and the relevance of the Association

The Rules of the UV4Plants association, information on membership, management committee and up-to-date news are available at `http//www.uv4plants.org`.

A new association with a history The origin of UV4Plants was the very successful COST Action FA0906 'UV4Growth' which was active from 2009 to 2014. It brought together photobiologists, molecular biologists, ecologists, meteorologists and stakeholders from agriculture and industry. Many new collaborations were started and new ideas developed.

Three large conferences, and several workshops and training events were organized. Four special journal issues were produced: *Physiologia Plantarum* **145**, 4, *Emirates Journal of Food and Agriculture* **24**, 6, *Plant Physiology and Biochemistry* **93**, and *Plant, Cell & Environment* **38**, 5.

Most participants, the members of the managing committee and the external evaluator all agreed in that a way of continuing and furthering the achievements of 'UV4Growth' was needed.

Invitation to Join UV4Plants UV4Plants welcomes a whole spectrum of members from both academia and industry, applied and basic research. Membership fees for 2016 are EUR 25.00 for students and retired staff, EUR 50.00 for academic members, and EUR 250.00 for industry members. See `http://www.uv4plants.org/news/invitation-to-join-our-association/` or contact `mailto:secretary@uv4plants.org` for details.

UV4Plants

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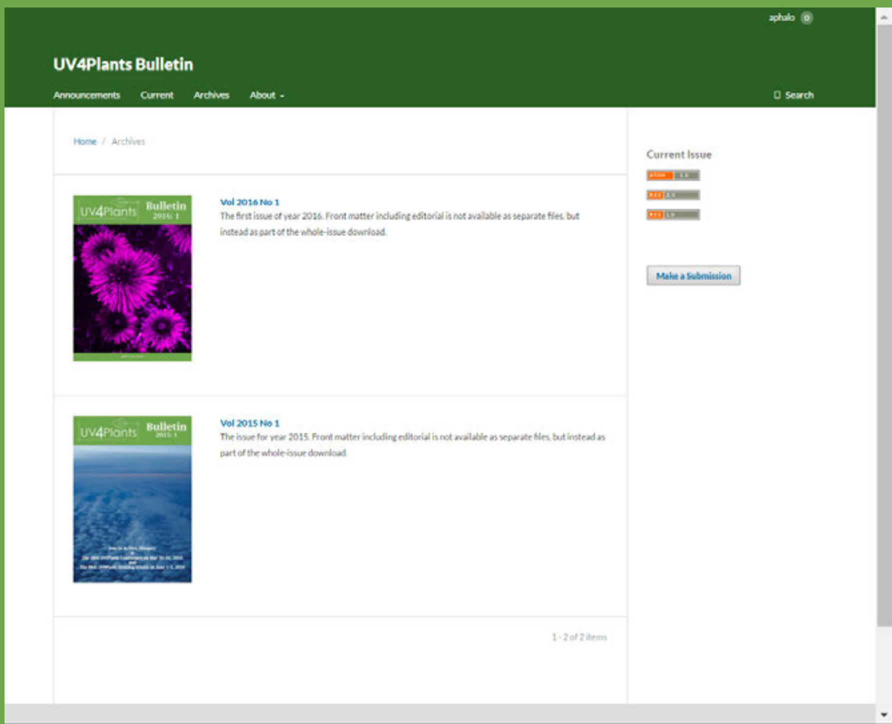

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