TARTU OBSERVATORY
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Radiative Transfer in Vegetation and Juhan Ross

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24-25 August 2017. Juhan Ross Legacy Symposium, Tõravere

My scattered thoughts

- about the historical situation how Juhan Ross came to the problem and how the radiative transfer studies developed. Special attention on early years (1960s and 1970s)

- on the role of radiative transfer studies in remote sensing and plant physiology

To better understand all the scientific issues, we have to keep in mind the historical situation

- Soviet Union in the post-war time
- Multiple repressions by the Stalin regime
- Juhan Ross was among those who were repressed due to his past (served in the Finnish Army during World War II). He was lucky not to be expelled from the Tartu University
- Juhan Ross managed to graduate Tartu University as a theoretical physicist in 1951. As a kind of punishment, he was sent to work as a head of Tartu Actinometric Station at the Institute of Physics and Astronomy – quite far from theoretical physics

Why radiative transfer (RT) in vegetation?

- At first, J. Ross studied actinometric instruments and methodologies of measurements and soon (1957) had his PhD (candidate) degree. Then for him the problem arose what should be a topic for his next degree - doctoral theses (DSc)
- Vegetation as one of the surface types thus influencing the upward and downward atmospheric solar radiation fluxes. Ross himself and **Heino Tooming** from his group had some experience of measuring vegetation integral shortwave albedo by pyranometers. First measurements already in 1953
- Some Russian colleagues including **Yurii Yanishevskii** (designed all the actinometric instruments in Russia) and Russian academician **Anatolii Nichiporovich** recommended studies of solar radiation regime in vegetation. An idea was suggested by Nichiporovich that through selection it could be possible to create new agricultural plants capable to absorb available solar radiation in an optimal way to increase plant production. Nichiporovich's main idea was to find optimal leaf angles to get a maximum photosynthetic production

Anatolii Aleksandrovich **Nichiporovich** and Cees **de Wit** (the tall man), Třebon September 1969

Some WORKS by Nichiporovich (1899-1996)

Fotosintez i teoriia polucheniia vysokikh urozhaev (Photosynthesis and theory of getting high crop yields). Moscow, 1956. (*Timiriazevskie chteniia*, XV.)

Fotosinteticheskaia deiatel'nost' rastenii v posevakh (Photosynthetic activity of plants in crops). Moscow, 1961. (With others.)

Teoreticheskie osnovy fotosinteticheskoi produktivnosti (Theoretical basis of photosynthetic productivity). Moscow, 1972. (Coauthor and editor.)

Radiative transfer in vegetation

- As a physicist, J. Ross realised that quantitative physical relations between canopy structure and absorption of photosynthetically active radiation are needed to study the problem of optimum canopy structure problem in vegetation canopies. Two main possibilities emerged
  - Geometric optics (GO) approach
  - Radiative transfer (RT) approach
- Some previous research existed in Russia, such as works by Ivanov (1932, 1946) and Shifrin (1953). K. Shifrin was the first to apply the turbid medium concept and RT approach to simulate vegetation albedo. The turbid medium concept seemed to be more attracting, was accepted and further elaborated by J. Ross
- From 1957 systematic studies of RT in vegetation started in the lab lead by J. Ross

Juhan Ross and Heino Tooming

Juhan Ross – my supervisor

- It was 1962. I was a fourth-year student of mathematics at Tartu University. Once, during a break between two lectures, a man in his 30-s came to me and introduced himself as Juhan Ross from the Institute of Physics and Astronomy. He asked if I would join his group to solve integro-differential equations of radiative transfer
- After some hesitation, I agreed. Although I had no idea about the radiative transfer equations. Ross asked me to find a Russian translation of the Chandrasekhar's book 'Radiative Transfer' in the university library and to start studying the book
- I remember that I was disappointed when the main task Ross put on me was to derive analytic expressions for the two-stream approximation of RT equation. The formulas were extremely lengthy and rather inconvenient to handle
- His stile of further supervision was giving me totally free hands

Beginning of radiative transfer (RT) studies

- It is logical that Ross chose the RT equation approach for vegetation
  - RT problems were extensively studied in the Soviet Union, mostly due to neutron physics, but also by astronomers and atmospheric physicists. Already in 1962 Juhan Ross was convinced that the RT equation should play a central role in solving the problem of radiation extinction and scattering in vegetation. By that time, he had formulated the extinction (G-function) and scattering (phase function for the elementary volume) coefficients in the RT equation
- In parallel, Ross initiated extensive field measurements of vegetation structure, radiation fluxes and photosynthesis, mostly in agricultural crops
- The photosynthesis studies within the Ross lab. The initial task was to derive reliable quantitative relations btw leaf photosynthesis and PAR. Later a photosynthesis subgroup lead by Agu Laisk (incl Vello Oja, Heino Moldau, etc) was formed

An early problem related to RT in vegetation was its shortwave integral albedo. J. Ross applied a RT equation based approach

Ю. К. РОСС **К ТЕОРИИ АЛЬБЕДО РАСТИТЕЛЬНОГО ПОКРОВА**

ИНСТИТУТ ГЕОЛОГИИ И ГЕОГРАФИИ АН ЛИТОВСКОЙ ССР
НАУЧНЫЕ СООБЩЕНИЯ, Т. XIII, 1962

CONCERNING THE THEORY OF VEGETABLE COVER ALBEDO

Plant canopy albedo was calculated by simulating the canopy as a turbid medium. Radiative transfer (RT) equation was introduced already here

$$\cos\vartheta \, \frac{\partial i(\tau, r)}{\partial \tau} = -i(\tau, r) + \frac{1}{4\pi} \int_{4\pi} p(r, r')\, i(\tau, r')\, d\Omega' + \frac{S(\tau, r_s)}{4\pi}\, p(r, r_s) + \frac{1}{4\pi} \int_{2\pi} p(r, r')\, d(\tau, r')\, d\Omega' \qquad (1)$$

The optical thickness τ was described by biomass volume density. Later in this study, scattering phase function $p(r.r')$ was supposed to be spherical and the RT equation was solved by a two-stream (Schwarzschild) approximation. A year later, instead of biomass, foliage area was considered

Turbid medium concept and RT equation

- Vegetation was simulated by Ross as an unisotropic horizontally homogeneous turbid medium consisting of tiny infinitely thin plates having certain statistical distribution of their inclination and azimuth angles and scattering (reflection/transmission) properties
- The respective RT equation was formulated. Everything seems to be rather simple today, but it was not so evident that time in 1960s
- The geometrical structure of plant canopy was described by the vertical distribution of foliage area volume density (e.g. m2/m3) and distribution of zenith angles and azimuths of leaf normals. Is this sufficient to describe the RT process?
- The optical properties of leaves are described by leaf scattering phase function. How to define the leaf phase function and that of an elementary volume?
- The radiation conditions at the lower surface described by albedo or reflectance factor of the soil surface

In 1960s Juhan Ross initiated the RT research in all main aspects

- Theoretical studies by applying the RT equation approach
- Experimental studies by field measurements in agricultural crops and leaf optics measurements in the lab
- Designing and manufactoring new original instruments for the measurements of canopy structure and solar radiation within agricultural crops

Soon the problems of extinction of integral shortwave radiation were solved

H. Tooming, J. Ross. 1965. Extinction of integral shortwave radiation by different maize crops. In: Voprosy radiatsionnogo rezhima rastitel’nogo pokrova. Institute of Physics and Astronomy, Academy of Sciences Estonian SSR. Tartu, 65-72

Coefficient of transmission of integral shortwave radiation as a function of leaf area index for different maize crops at various solar angles. Experiments from Estonia and Moldova

However, PAR extinction was needed for the photosynthesis!

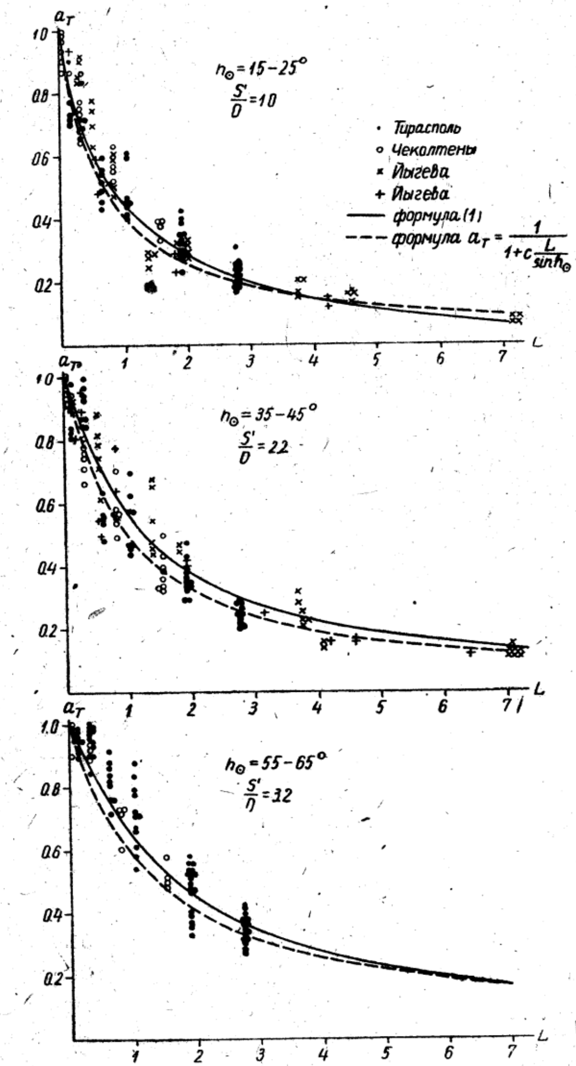


Рис. 2. Ослабление интегральной радиации различными посевами кукурузы в зависимости от относительной площади листьев и высоты Солнца.

Semiempirical formula to approximate the empirical data, sum of two exponents

$$a_T(L,\ h_\odot) = \frac{\frac{S'}{D}\, e^{-c_1 \frac{L}{\sin h_\odot}} + a_D}{1 + \frac{S'}{D}} + c_2\left(e^{-c_3 c_1 \frac{L}{\sin h_\odot}} - e^{-c_1 \frac{L}{\sin h_\odot}}\right), \quad (1)$$

Important work: J. Ross. Mathematical modelling of PAR field in plant canopies. In: Actinometria i optika atmosfery. Nauka, Moscow, 1964, pp 251-256

Ю. К. Росс

Институт физики и астрономии АН Эст. ССР, Тарту

МАТЕМАТИЧЕСКОЕ МОДЕЛИРОВАНИЕ ПОЛЯ ФОТОСИНТЕТИЧЕСКИ АКТИВНОЙ РАДИАЦИИ (ФАР) В РАСТИТЕЛЬНОМ ПОКРОВЕ

$$\gamma(z,\ r',\ r)=\int_{4\pi}\gamma_L(z,\ \widehat{r'r_L},\ \widehat{rr_L})\,g_L(z,\ r_L)\,|\cos\widehat{r'r_L}|\,|\cos\widehat{rr_L}|\,\frac{d\Omega_L}{4\pi} \tag{4}$$

$$\cos\vartheta\,\frac{\partial i(z,\ r)}{\partial z}=-\varkappa(z)\,\Gamma(z,\ r)\,i(z,\ r)+\varkappa(z)\int_{4\pi}\gamma(z,\ r',\ r)\,i(z,\ r')\,\frac{d\Omega'}{4\pi}+$$
$$+\frac{\varkappa(z)}{4\pi}\gamma(z,\ r_\odot,\ r)\,S(z,\ r_\odot)+\frac{\varkappa(z)}{4\pi}\int_{2\pi}\gamma(z,\ r_D,\ r)\,d(z,\ r_D)\,d\Omega_D, \tag{5}$$

где

$$S(z,\ r_\odot)=S_0(r_\odot)\,e^{-\sec\vartheta_\odot\int_0^z\varkappa(z)\,\Gamma(z,\ r_\odot)\,dz}; \tag{6}$$

$$d(z,\ r_D)=d_0(r_D)\,e^{-\sec\vartheta_D\int_0^z\varkappa(z)\,\Gamma(z,\ r_D)\,dz} \tag{7}$$

и

$$\Gamma(z,\ r)=\frac{1}{4\pi}\int_{4\pi}g_L(z,\ r_L)\,|\cos\widehat{rr_L}|\,d\Omega_L. \tag{8}$$

We see the RT equation already in the form we know it now. However, a few notations were different

- *G*-function is denoted by *Γ* (*uppercase gamma*)
- Scattering phase function for the canopy layer is denoted by *ϒ* (*lowercase gamma*)
- Foliage area volume density is denoted by *κ* (*kappa*)

- As a source function, both components, the direct solar radiation and diffuse sky radiation are considered

Geometrical structure of canopy was described by the same quantities as we do it now. However, some other quantities appeared

- Foliage area volume density
- Foliage normal inclination and azimuth distribution
- Leaf size distribution
- Distribution of adjacent foliage elements
- the last two needed to define a kind of a general statistical operator

3) $g_\sigma(z, \sigma)$ — функция распределения площади отдельных листьев, причем $g_\sigma d\sigma$ — вероятность того, что в слое dz листья имеют площадь между σ и $\sigma + d\sigma$.

Условие нормирования

$$\int_{\sigma_{\min}}^{\sigma_{\max}} g_\sigma(z, \sigma)\, d\sigma = 1.$$

4) $g_{\alpha, s}(z, \alpha, s)$ — функция распределения соседних элементов биомассы в горизонтальной плоскости, причем $g_{\alpha, s}(z, \alpha, s)\, ds$ — вероятность того, что в слое dz соседний элемент биомассы находится в области $dS = s ds d\alpha$ вокруг точки $P = (\alpha, s)$, где s — расстояние до точки P и α — азимут горизонтального направления.

Условие нормирования

$$\int_0^{2\pi} d\alpha \int_0^{\infty} g_{\alpha, s}(z, \alpha, s)\, s ds = 1.$$

Importance of statistical treatment pointed out

- A general statistical operator $Ri_\lambda(ds)$ was formally introduced describing the influence of canopy foliage on the probability distribution of the intensity of radiation field. If I remember correctly, Ross never specified it and never returned to this operator

$$\tilde{R}i_\lambda(ds)\, fi_\lambda(z,\ r,\ I) = fi_\lambda(z+ds,\ r,\ I), \tag{3}$$

- Assumption that plant canopies are horizontally homogeneous in a statistical sense
- The statistical-probabilistic approach vs turbid medium concept. Are they equivalent? Later we realised that turbid medium theory not able to describe the hot spot
- Intensities of radiation as random functions. Average radiation fluxes are not sufficient for the photosynthesis study

Ross, J. and Nilson, T. 1968. In: Actinometry and atmospheric optics. Tallinn, Valgus, pp 263-281

The main quantities and equations as we know today were given

A general RT equation for multi-component vegetation for the direct solar radiation component

$$\cos\vartheta \frac{\partial i_{\lambda S}(z,\vec{r})}{\partial z} = -\sum_k u_k(z)\, G_k(z,\vec{r})\, i_{\lambda S}(z,\vec{r}) + \sum_k u_k(z)\,(1/\pi)\int_{4\pi} \Gamma_{\lambda k}(z,\vec{r}\,',\vec{r})\, i_{\lambda S}(z,\vec{r}\,')\, d\Omega' + \sum_k u_k(z)\,(1/\pi)\,\Gamma_{\lambda k}(z,\vec{r}_\odot,\vec{r})\, S_\lambda(z,\vec{r}_\odot), \quad (11)$$

A simplified RT equation if the optical properties and leaf angles do not change along with the vertical coordinate

$$\cos\Theta \frac{\partial i_S(L,\vec{r})}{\partial L} = -G_L(\vec{r})\, i_S(L,\vec{r}) + \frac{1}{\pi}\int_{4\pi} \Gamma_L(\vec{r}\,',\vec{r})\, i_S(L,\vec{r}\,')\, d\Omega' + \frac{1}{\pi}\Gamma_L(\vec{r}_\odot,\vec{r})\, S(L,\vec{r}_\odot), \quad (11a)$$

Three components of the radiation field inside a plant canopy. Separate treatment reasonable

1. Penetration of direct solar radiation through the gaps in foliage – a purely geometrical problem. However, the penumbra effect should be considered
2. Penetration of diffuse sky radiation through the gaps in foliage
3. Scattering (transmission and/or reflection) of the first two components on the foliage and soil

- Importance of gap fraction and theoretical formulas for gap fraction, esp for the first two components. A pure geometrical problem, spectral invariant, if you wish
- Full RT problem needed to solve for the third component

Theoretical RT studies

- Solving the RT equations was a real problem because of limited computing capabilities. So we preferred analytical methods. First-order scattering approach for the PAR region applicable
- We were extremely happy to find an exact solution of the RT problem for a plant canopy with horizontal Lambertian leaves (1968)
- Along with the development of computers, solving the transfer equation became possible
- Juhan Ross was among the first who applied Monte-Carlo methods to solve the RT problem. First attempts together with Valeri Kanevski (1980). Later with Alexander Marshak

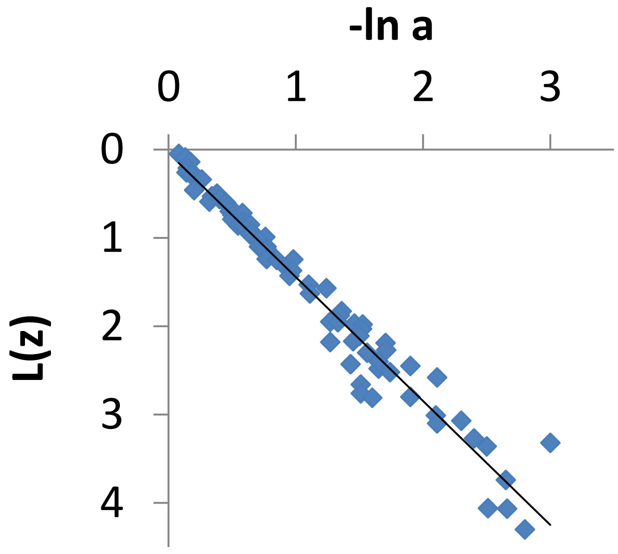
Field studies and designing of radiation instruments

- Main problem - Photosynthetically Active Radiation (PAR) extinction within plant canopies
- Available instruments in 1960s - integral shortwave pyranometers. A problem - the spectral composition of radiation changes along with depth in the canopy due to spectrally selective absorption in the visible and NIR
- Later on first spectral instruments were designed in house and built. An approximate method suggested by Tooming how to derive PAR attenuation from the measurements in integral shortwave
- Long horizontal rods installed within agricultural crops where the sensors moved to get more or less reliable averages of fluxes and representative statistics. Huge spatial/temporal variability of radiation fluxes detected. Agu Laisk designed a statistical analyzer of radiation fluxes (1965)

Measurements of canopy structure

- Leaf angle and azimuth. Agu Laisk designed a simple instrument to measure leaf angles (1965)
- Vertical distribution of leaf area – mostly by stratified clipping
- Spatial distribution pattern of leaves – Inclined point quadrat instrument. Main idea was to study the contact distribution: is the spatial Poisson distribution applicable?
- Gap fraction measurements. Photometric rod. Agu Laisk's 'Mouse' (1974). First fisheye lens presented by Margaret Anderson in 1969

A relation btw the logarithm of gap fraction (ln a) and downward cumulative leaf area index L(z). Maize, at 45°. Inclined point quadrat instrument. Similar results by the 'Mouse'



No real communication with the western scientists possible. Ed Lemon (University of Connecticut) was the first Western scientist to visit us

Juhan Ross introducing our home-made point quadrat instrument to Ed Lemon (from left: Agu Laisk, Herbert Niilisk, Ed Lemon, Olev Avaste, Juhan Ross) 1969

Canopy structure measurements

Maize crops in 1963
Leaf angle measurements,
Leaf area vertical distribution
by stratified clips

Photos Madis Sulev

Gap fraction measurements. Agu Laisk's mouse, inclined point quadrat, hemispheric photos

Agu Laisk with his 'Mouse'.

(We did not carry out gap fraction measurements in winter)

The fisheye lens gifted by Margaret Anderson was intensively used for many years

The point quadrat instrument in use on a potato field

Measurements of leaf optical properties

- Measurements of leaf scattering phase functions
- Heino Moldau designed a special goniometer with changable bandpass interference filters for lab measurements and published his main results already in 1965. Also with polarized light

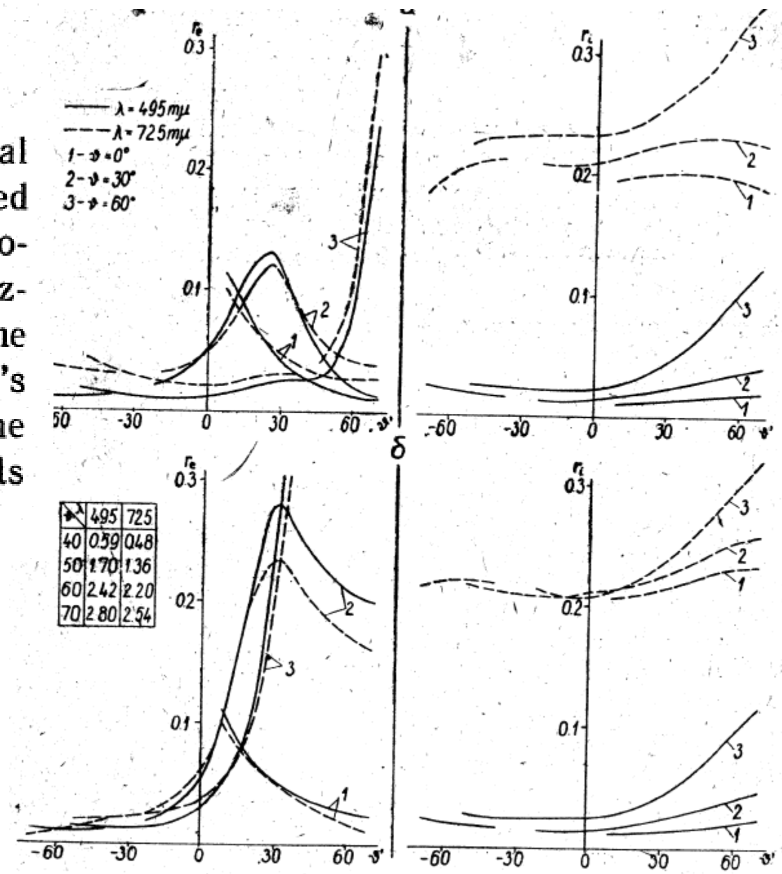
In: Voprosy radiatsionnogo rezhima rastitel’nogo pokrova. Institute of Physics and Astronomy, Academy of Sciences Estonian SSR. Tartu, 1965, 96-101

ON THE USE OF POLARIZED RADIATION TO ANALYSE THE REFLECTION INDICATRIXES OF LEAVES

H. Moldau

The polarized and unpolarized components of the spectral reflection indicatrixes of leaves are measured if the polarized radiation strikes upon. It is shown that the polarized component does not depend on the wavelength, just as the unpolarized one greatly depends on it. The conclusion is drawn that the polarized component is the result of reflection on the leaf's surface and the unpolarized component comes mainly from the interior of the leaf. Also the external and internal components of the spectral albedo are calculated.

Polarized and depolarized components of maize leaf at 495 and 725 nm. Angle of incidence 0, 30 and 60°. s-polarized (upper Figures) and p-polarized (lower) light



ϑ \ λ	495	725
40	0.59	0.48
50	1.70	1.36
60	2.42	2.20
70	2.80	2.54

Рис. 1. Поляризованная r_e и деполяризованная r_i составляющие индикатрисы коэффициентов яркости листа кукурузы.

Optical model for a plant leaf by H. Moldau (1967)

- Two components of the leaf reflectance were distinguished and separately treated
  - Specular component due to reflection from the undulating leaf surface, described by the Fresnel formula. Surface roughness (distribution of surface normal's inclination) and refraction index were needed. By the same time Ü. Mullamaa from our lab had derived surface reflectance properties for the sea surface
  - Internal reflectance/transmittance component, theoretically derived from the respective RT equation

In: Phytoactinometricheskie issledovaniya rastitel'nogo pokrova (in Russian). Institute of Physics and Astronomy, Academy of Sciences Estonian SSR. Tartu, 1967, pp 89-109

OPTICAL MODEL OF PLANT LEAF

H. Moldau

This report proposes a matematical model of plant leaf which permits to explain several regularities in the spectral diffusing properties of them. The reflection indicatrixe is divided into external and internal components. The first calculated on the base of Fresnel reflection from a rough surface. The interior of the leaf is assumed to a plane-parallel layer of absorbing-diffusing medium, restricted from both sides with two reflecting surfaces. Some parameters, needed for calculation (refraction index and roughness of the surface) are determined by means of optical methods. The mean parameters of leaf's interior (absorption and scattering coefficients, optical thickness) are evaluated.

New way of thinking was needed

- Ross’ slogan for many years: To introduce physical, quantitative methods into the research in biology

- Ross introduced a new term - phytoactinometry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Main books on radiative transfer in vegetation by Juhan Ross

- **Ross, J.** 1975. The radiation regime and architecture of plant canopies. Leningrad, Gidrometeoizdat, 342 pp (*Russian*)
- **Ross, J.** 1981. The radiation regime and architecture of plant stands. Junk Publ., The Netherlands, 391 pp
- **Myneni, R.B.** and **Ross, J.** (eds). 1991. Photon-vegetation interactions. Applications in optical remote sensing and plant ecology. Springer-Verlag. Berlin, Heidelberg, New-York,…,565 pp
- **Kanevski, V.** and **Ross, J.** 1992. Laser remote sensing of vegetation, *Advances in Bioclimatology,* Springer, Heidelberg.
- **Ross, J., Knyazikhin, J., Kuusk, A., Marshak, A.,** and **Nilson, T.** 1992. *Mathematical Modeling of the Solar Radiation Transfer in Plant Canopies,* Gidrometeoizdat, St. Petersburg, 195 pp. (*Russian*)

Juhan Ross legacy

- All vegetation reflectance models used in remote sensing very much rely on the radiative transfer theory or at least on the concepts introduced by Juhan Ross

- The same holds for the plant photosynthesis and productivity models where solar radiation is the most important input

- No doubt, Juhan Ross has changed the paradigm in vegetation productivity and remote sensing science

Concept of vegetation as a turbid medium

- Geometrical optics vs turbid medium approach. Turbid plate medium. Plant leaves are modelled as tiny very thin small plates
- Problems with the turbid medium and RT equation
  - So-called elementary volume, how should it be defined? Controversial assumptions
    - Should be large enough to contain many particles, so that the statistical leaf angle distribution can be applied
    - No mutual shadowing should exist within an elementary volume
    - Can we assume that the spatial distribution of canopy elements is random? Structures of individual plants seem to be semi-regular
  - How to describe the scattering properties of leaves and of an elementary volume

- Plant canopy optically very thick compared with the atmosphere

Problems with the hot spot

- RT equation does not consider leaf size
- ‘Memory’ of a photon related to the photon’s free path
- Maybe Ranga can share his experience with trying to modify the RT equation

Did the RT-based approach introduce anything revolutionary into the vegetation studies?

- We may be proud of some results obtained from the RT-based approach. Like the Ross-thick and Ross-thin kernels in the kernel-driven algorithms of analyzing the remotely sensed BRDF data. In fact these kernels were obtained from the two-stream approximation, I had to derive as my first task in Ross' group
- We can understand the main qualitative and quantitative relationships concerning solar radiation extinction, scattering and absorption. Some general properties of radiation scattering in plant canopies uncovered, e.g. by the analysis of eigenvalues and eigenvectors of the RT equation
- However, the amount of efficient and robust applications has been less than we expected. Including the solution of the inverse problem
- The original problem of optimum leaf angles was almost forgotten

Why the RT-based models have given too few efficient applications into the practice?

- The predictive power of RT-based models has been relatively low (the same seems to be in atmospheric RT, too)
- Too many important input parameters to determine, difficult to find a simple parametrization
- Real plant canopies have a complex structure and it is impractical to measure all the details of structure
- Large spatial variability of radiation intensities within the canopy, difficult to test the theoretical formulas
- Principal problems with RT equation in plant canopies

More about the problem: A forthcoming Elsevier book chapter by Andres Kuusk

Comprehensive Remote Sensing, Volume 3
Terrestrial Ecosystems (ed Jing Chen)
Chapter 1
Andres Kuusk
Tartu Observatory, Estonia
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Chapter 1
Canopy radiative transfer
modeling

Monte-Carlo vs RT algorithms

- For Monte-Carlo or radiosity algorithms, less principal problems seem to exist compared with the RT concept
- Should RT and Monte-Carlo algorithms give the same average radiation field for the same canopy? We average the structure first and calculate the radiation intensities or calculate radiation intensities for a given (quasi-random) structure and then average the radiation intensities

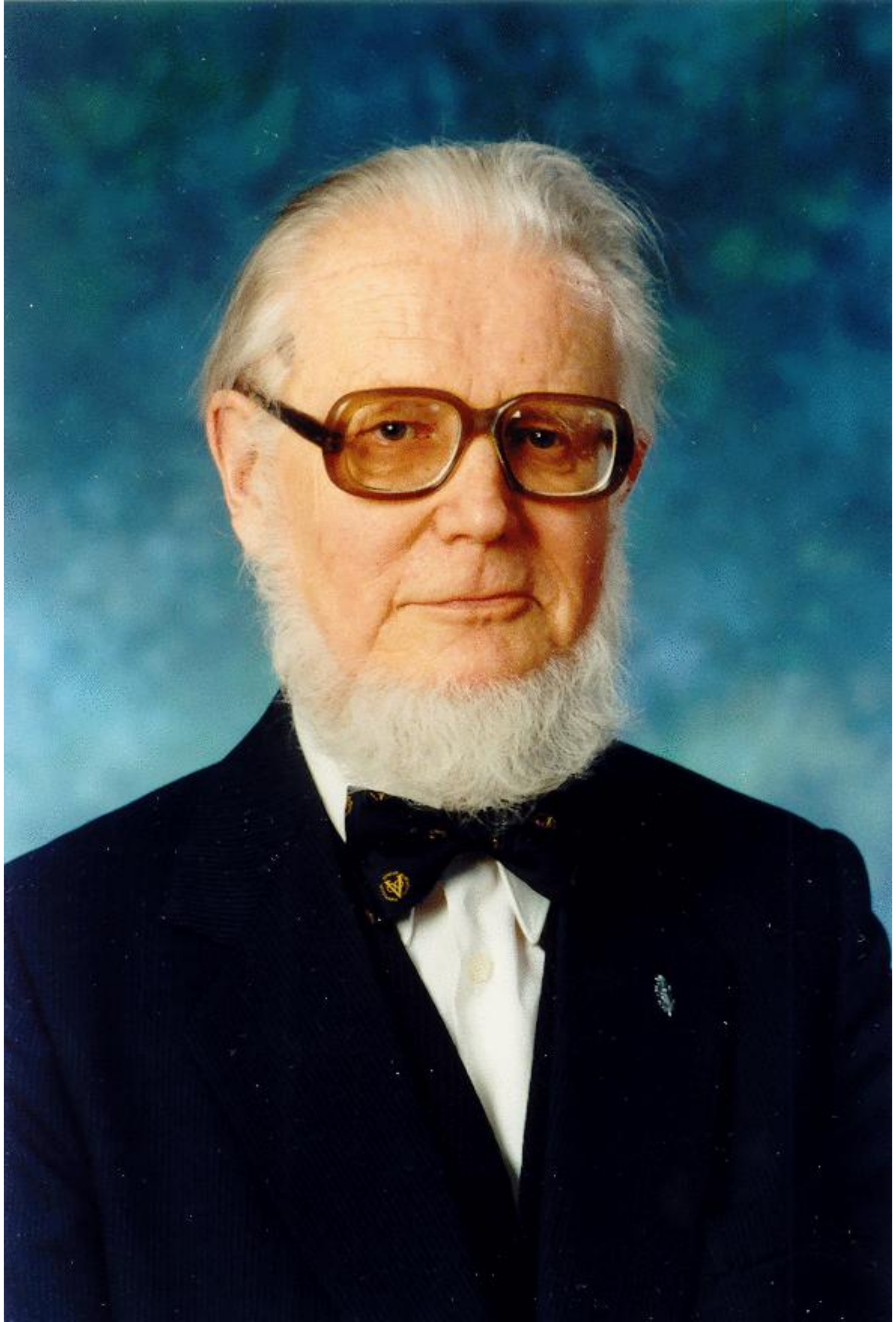
Juhan Ross’ main phenomenon - a science manager

- Excellent selection of new members into his group (Agu Laisk, Heino Tooming, Jüri Reemann, Heino Moldau, Madis Sulev, Herbert Niilisk, Andres Kuusk, Alexander Marshak, Matti Mõttus to just name a few of them)
- He was able to arrange leading Soviet specialists to be supervisors for his younger colleagues
- Ability to convince people that his scientific approach is worth of support (e.g. organizing photosynthesis studies in an astronomical observatory!)
- Activity in organizing scientific cooperation within the limits available this time (e.g., All-Soviet Union series of popular seminars called PUM: weather, yield, mathematics; Ökotoorium in Tartu; Finnish-Estonian cooperation in ecophysiology, etc)
- Always in the centre of attention in any post-conference party

On other activities of Juhan Ross

- Juhan Ross had a wide range of scientific interests, such as
  - Modelling the photosynthetic productivity of vegetation
  - Energy balance of atmospheric boundary layer and RT in the thermal infrared region
  - Latest activity – energy forest
- He took an active role in the Estonian independence movement in 1980s and 1990s

- Certainly, I was able to cover a small part of Juhan Ross contribution on the RT research in plant canopies
- I am happy if my presentation did provoke any discussion on the RT problems



Juhan Ross, the grand old man in Estonian science, biogeophysics in particular

Thanks for the attention!