INTERNATIONAL WORKSHOP ON MULTIANGULAR REMOTE SENSING: MEASUREMENTS, MODELS AND APPLICATIONS.

September 13-18, 1996
Beijing, P.R. China

WORKSHOP REPORT

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1. Changchun

On Friday September 13 a variety of international BRDF people met at the Youyi Binguan (Friendship Hotel) in Beijing, registered and readied themselves for a two-part meeting - the first International Workshop On Multiangular Remote Sensing (Measurements, Models And Applications).

The Meeting was organised by members of the Institute of Remote Sensing Applications (IRSA) of the Chinese Academy of Sciences (CAS) and of the Beijing Normal University. There was international help as well, especially from Alan Strahler's group at Boston University. The first part of the Meeting was held in Changchun, a city to the north of Beijing in Jilin. It is known as the Detroit of China due to its vehicle production industry and historically it is remembered as the Capital of Manchu Guo, the puppet state set up by Japan in 1931 with the last emperor Pu Yi as head. But neither of these brought us there. Near Changchun is the Jingyuetan Remote Sensing Test Site.

Operated by the CAS, the Test Site has a wide range of land covers and has been the site of many field experiments and validation campaigns. Since 1980, an extensive laboratory facility has been developed. In particular, we came to see the indoor Solar Simulation Laboratory. This is a large scale goniometer with an artificial source to simulate the sun and moveable positions for sun/sensor effects measurement. The target measured is a square metre of anything you can fit in a square meter. A small table top instrument has also been developed to allow multi-angular measurements of reflectance and transmittance at the scale of leaves.

We saw the site in operation and the data processed in quick time as 3D plots. There was considerable discussion of the various edge effects and conditions that make this type of facility similar or different to *in situ* measurements. We were all impressed by the facility. I wish we had one even if only to calibrate our field panels! But not all is lost, since we are welcome to define and conduct

experiments at Jingyuetan. Indeed, if field campaigns were made at the general site, example patches could be tested for complete BRDF at the same time. It beats using a Spectron SE590 out in the weather while the sun and sky change around you. Meanwhile, a graduate student can be measuring the leaves as well!

Nearby is a solar observatory on a hill top with a dome roof that opens allowing a range of continuous sun photometer and irradiance device data to be collected. Quite an investment has been made and in principle a high level of characterisation could be had at Jingyuetan - to a level we have no hope of matching in Australia at this time.

After a good lunch on Sunday September 15 (which by itself was probably enough to justify further collaboration and cooperative development) we flew back to (warmer) Beijing for the next phase of the Workshop.

2. Beijing

On the morning of Monday September 16 the talking and discussion part of the Workshop began. We were welcomed by a group of very senior and distinguished people from the CAS and the State Science and Technology Commission. Juhan Ross, the 'grand old man' of radiation in plant canopies and Alan Strahler (who is still quite young) gave Keynote Addresses which set the scene for the Meeting.

There followed two days (two half days and one full day) of very intensively packed presentations. The program as presented, with speaker (bolded) and topic is attached for you to read. The papers will be available in the near future for you to look more carefully at talks that are especially relevant to you. In this Report, I will limit my discussion to general impressions plus a detailed set of notes on the outcomes Discussion that occurred on Wednesday September 18

Of course, a primary outcome for such meetings is for people working in a field to meet, get to know each other if that has not happened before, exchange ideas both during sessions and at any other time that is available and jointly develop their ideas of the directions that need to be pursued into the future. All of these happened.

3. General Notes & Impressions

3.1 Parametric BRDF

It was very comforting to see how the recent simplifications to BRDF models (the 'kernel' and similar simple models) were performing well as tools in atmospheric correction and image brightness correction at

airborne, TM and AVHRR data scales. Simplified models and linearity are obviously fashionable but also provide very practical tools to describe and use BRDF for applications such as those above and others such as panel characterisation. Obviously, the scope for such techniques is about to increase with the launch of ADEOS carrying POLDER and will further increase as MODIS and MISR data start to come on line in a more distant time frame.

These developments were outlined in Talks [1-8], [2-5], [3-3], [3-5], [3-6] and [4-2]

3.2 Hospot Specific Instrumentation

Sig Gerstl [1-2] provided advance notice for an innovative mission to utilise the hotspot region from space using an active laser and tethered receivers. It is 'Bi-static Lidar' I guess and the technology is feasible. All that is needed is for the extra value of the information to be proven over not doing it! His ideas are not alone in that.

3.3 Field and Laboratory Instrumentation

There was a strong emphasis on field and laboratory measurement. In summarising his session, Juhan Ross said that the main advances have been in computer technology and in constructing measurement instruments. Instrumentation and measurement protocols are very difficult but essential components of the research and also of the applications. The ideas included field data for structural characterisation as well as radiometric measurements. In addition to the Changchun site, there is a goniometer in Italy at the European Goniometric Observatory (EGO) which is also producing many detailed studies of BRDF at the one square metre plot scale. It was clear, however, that the leaf measurements being taken at Changchun were the envy of most and we all hope to see outcomes being published and information made available in the future.

There is still a lot to be done relative to the 'scattering phase functions' of the objects that different user models and radiative models want and can deal with. Leaf measurements need to be linked to high spectral resolution data and plant physiological information (such as chlorophyll and pigments) as well. However, the tools are emerging to do this which did not previously exist. At the 'module' or 'branch' scale, Juhan Ross described an instrument for measuring scattering that is being used in Estonia (the 'Shoot Goniometer') and for short crops and other covers, the large indoor Goniometers at Changchun and ISPRA are obviously filling a need.

However, in order to relate models, measurements and the objectives of the users there is still some work to be done in describing and recording structure in the non-homogeneous canopies we mostly work with. Juhan Ross and Tiit Nilson were especially adamant of the need to introduce such protocols of field description and measurement and emphasised that they need to relate to the end use. Given the limited relationships between (say) traditional forestry data and radiation data this may mean the definition of a set of new phytometrical measurements. The Chinese work by Xiang Yueqin and Wang Jindi ([1-11], [1-12]) is very interesting in this regard.

Other talks covering this area were: [1-1], [1-4], [1-5], [1-9], [1-10], [2-9] and [3-1]

3.4 Modelling & Inversion

The recent main advances in modelling seem to have been computational rather than by changes in the physics and/or mathematics. There are now a well defined set of models that can adequately describe the BRDF of structured land covers. What is not so common are the parameters of the component properties of the models (such as leaf phase functions!) and there is still scope for computational simplifications and more robust techniques for inversion.

Andres Kuusk and others described a number of uses of parameter inversion with Landsat TM and AVHRR data. With Landsat TM data, Kuusk was inverting chlorophyll content using relationships obtained from field and laboratory measurements. Inversion is obviously the aim of this work and has still to be made simpler and more robust.

As a complete test base for models and measurements associated with the EGO, Michel Verstraete described the Monte-Carlo RayTran model which has been running on a supercomputer at ISPRA. Able to be linked to an L-System model of the land surface it provides a good base for model testing and data interpretation. He also described work in which the leaf structure is modelled by simple geometric forms (cylinders, spheres and sheets). He was keen to form an 'Observation Protocol' for the data that will be generated in the future.

Such work obviously sits at the interface between measurement and modelling. At this advancing stage of the development of the BRDF research the two are clearly dependent and complementary.

Related Talks were: [2-1], [2-2], [2-3], [2-6], [2-7], [2-8], [3-1], [3-2], [3-3], [3-4], [3-5], [3-6], [3-8], [3-9] and [4-1].

3.5 Remotely Sensed Data

There were many data types discussed. These ranged from the use of existing data types, such as aerial photography, Landsat TM, AVHRR and airborne data (such as Daedalus data) to simulations of the emerging data types such as POLDER, MISR and MODIS.

Quite a variety of airborne instruments exist now which can obviously be used for research as well as for their prime objective as development tools for space borne instruments. These include ASAS, the POLDER simulator and MISR Airborne Simulator (MAS). These can be regarded separately as tools for mapping just as the final spaceborne tools will be. Their advantages are those of airborne data - flexible deployment, control over calibration and ancillary data.

Papers discussion these include: [1-6], [1-7], [1-8], [3-2], [3-3], [3-4], [3-5], [3-8] and [3-9].

3.6 Scale

There were many ranges of scale presented at the workshop. Information was obtained and models discussed for the sub-millimetre scale of ice crystals, through soil grain, leaf, branch, crown and canopy up to AVHRR scale. It seemed to be unquestioned that BRDF and Hotspot effects translated easily through these scale changes.

I believe the area of BRDF and Hotspot effects is perhaps almost unique in the way its significant invariants do transfer across scales. Yet it is not all so easy. There are many issues of scale that are as yet neglected. Relationships between phase functions for the ‘grains’ listed above and those of the components making them up have no complete theory and this is a major challenge. Not wanting to push a barrow necessarily, I would mention that this scaling undoubtedly involves at least spatial variance and correlations and that the ‘mean’ effects we call BRDF and the Hotspot are not themselves sufficient to describe the scaling.

There were papers involving many scales but none on ‘scale’. There was one which discussed variance [2-4].

3.7 The Hunter and the Dog

Juhan Ross pointed out that in Estonia in the forestry and ecology ‘hunts’ it has been traditional to regard the Forester or Ecologist as the Hunter and the physicist as the Dog. However, he noted that the traditional forestry and ecology cannot handle the information our science is able to provide nor cope with the scales we can encompass.

He claimed that in radiation ecology it is time for the physicist to become the Hunter and the Dog.

I agree. In other cases we have for years been asked by climate modellers and others to provide crude summarising parameters for models whose handling of the radiation fields would make any remote sensing specialist weep. Our science is moving into data spaces unknown to our 'Hunter' buddies. It is time to hunt down what *we* can find out about the world that no one else can reach and then also drop it on their clean boots with wagging tails!

4. The Closing Discussion of September 18

The following discussion is an expansion of the set of notes provided and taken by Alan Strahler as Chair and facilitator of this important discussion. He is thanked for the privilege he gave me to use his notes but is not to blame for the [embellishments].

4.1 Initial Discussion Starter.

4.1.1 Why Study BRDF in Remote Sensing?

(i) Improve understanding of physical scattering mechanisms of surface covers and interaction with soil and atmosphere;

(ii) Retrieval of surface parameters by inversion. But which parameters? See below ...

[Maybe not just inversion but also by interpretation and pattern recognition]

(iii) Correction of angular effects in imagery allowing users to make their own inferences.

[Users often want to apply image processing to mosaics. Image processing implies spatial stationarity which angular variations disrupt. We need the make the data at least 'quasi-stationary]

Key Problem: " ... the main limiting factor remains - obtained by remote sensing, vegetation parameters quite poorly express the main biological processes - photosynthesis, respiration, transpiration, allocation etc of growing vegetation." (Juhan Ross)

That is, Radiation Parameters are not the same as Ecological Parameters.

[However, Ross has the view that the fault is not with RS but there needs to be a re-appraisal of measurement models on both the ecological and remote sensing sides. That is, it is time the Dog became the Hunter and the Dog. This is not just the case in vegetation cover. Linking the user scene measurement/descriptive model with the radiative scene measurement/descriptive model is the Key issue in most applications.]

4.1.2 What is Needed?

Models: Not a problem
Inversion strategies can use improvement

[There was not complete agreement here. Bernard Pinty, the Modeller's Modeller (i.e. a Modeller who is such a Modeller that even Modellers call him a Modeller), felt that better models are still needed. Personally, I think the current models are advanced enough and are not what is pushing the boundary. It is a common statement in water radiation models and atmosphere radiation models that the current limitations are not in the models but in our knowledge of the physical parameters and properties that are needed to run the models. Land models are not as well established but the statement is, I think, the same. Better *Inversion* theory, of course, can provide many of these properties in addition to the scene parameters.]

Data: "Point" measurements for model development and validation
Lab: Leaf scattering measurements
Goniometric measurements of targets
Field: Goniometric measurements of real targets in the atmosphere
"Area" measurements to extend information spatially
Field campaigns, aircraft data
Satellite data - AVHRR, POLDER, MODIS, MISR & Spot-Vegetation

[Measurement and Validation issues are a major issue and provide the current challenge. At all stages and scales it is also important to introduce the correct environmental information so that the radiation scene models and the user scene models can be related. For example, are leaf measurements useful without pigment and high spectral data measurements? Can fluorescence data provide the link? In each case above there is an issue of standardisation and information cataloguing. What is the minimal data set and descriptors such that the data can be used by others? What standardisation is needed in measurement techniques as well as information recording? Is a field reflectance useful if (at least) the fraction of diffuse radiation is not

recorded? Is a leaf scattering reading useful if leaf absorption spectrum and/or fluorescence spectrum is/are not recorded?]

Mechanisms Sharing models?
Sharing Data?

[The above applies. There need to be common bases for model and data comparison and validation. Perhaps there are standard targets which can be used to test instruments and standard scenes to test models. But how do you adequately define and parametrise these? The suggestion is recorded later for some form of email discussion area. Maybe a listserver is a good start. However, perhaps a full Web Site is what is needed with pointers to data owners and sites, model owners and sites plus a compendium of proposed standards and methods for model and field analysis. The EOC is starting such a beast. For people who are not on the internet, an HTML version could be supplied regularly by diskette for off-line browsing!]

4.1.3 What's Next for This Workshop?

Biennial Meetings?
1998 in ISPRA or Toulouse

[I suggest also that the regular slot at IGARSS be maintained as a continuity placer meeting. This plus the 'Web' site may be enough to keep the Beijing momentum going forward.]

4.2 General Discussion

The general discussion that followed was recorded in point form by Alan Strahler. I have repeated the points with some expansion but usually without [embellishment] as I remember them from the time. Where a change may change the meaning I have recorded it in [brackets]. In addition, I have re-ordered the points and collected them under a number of headings reflecting my viewpoint and interests.

[The classification arises from my way of describing what most of the modellers and measurers are going through. That is, they decide on a 'grain' for their objects, define a set of properties or functions attributable to the grains and arrangement and geometric properties attributable to the collection of grains. The complete system is the scene model. This "grain" model must be relatable to both the radiation model and the user model of the world if the activity is to be completely successful. When they go out to measure the world, the relationship between the measurements and this scene model is the measurement model. If the data are to be useful there must be a good base measurement model.

For example, in plant canopies, you must decide if you are working at the leaf and stem level, the 'shoot' or 'module' level, or whether you can start at the crown level, or stand level or community level. Foresters tend to think of forests as collections of tree trunks with aggregate basal areas and stem size distributions and make appropriately scaled measurements, but ecologists have a bit more flexibility. Crop modelling is usually best done at the leaf and stem level although recent data suggest the architecture of the way these group on plants is also of significance for modelling.

In each case, if you are an ecologist, for example, you must ensure the description is rich enough in scene model grain and measurement model scale to accommodate the outputs of interest such as CO_2 flux, water flux or energy balance components. It must be powerful enough to accommodate dynamics (such as succession) if this is the objective. For the remote sensor, it must be equally flexible and sufficient if these outputs are the objectives but it must particularly be sufficient to describe the radiation *measurement* model and link to the sensor *measurement* model.

The relationship between the user scene model and the radiation scene model involves measurement scale. The measurement scale may be finer or coarser than the user scene model and this relationship is important for choice of analytical approach. In the Strahler et al. terminology, the radiation measurement model may be (Low) L- or (High) H-resolution relative to the scene model.

Using these ideas, the points people have made are collected under four headings:

1. Relationships Between User and Radiation Models

2. Tools for Measurement of Properties & Structure

3. Radiation Measurement Models & Inversion

4. Infrastructure Issues

The collection 1. is of special significance and is the longest. It includes how to describe the scene as well as the issues of Standards, User Viewpoints and User Attitudes. Typical management views in some of the programs may reflect user views and question whether BRDF based methods really work, whether there are too many models and too few products and complain that there are too few standards and less quality control. What are the products?

Bernard Pinty made the suggestion that it is too early for standards. I fear that if it is too early then it is already too late.

As a final category I have listed Infrastructure Issues. These are things we can do as a "BRDF Community" to take things forward.]

4.2.1 Relationships Between User and Radiation Models

Sig Gerstl: Parameter match must be made. Ecologists see the [same] "sun" for their applications. We need to locate the same phenomena that give the biological effect and the radiation effect. Canopy architecture is an overlap area. We need structure-based vegetation classifications.

Andres Kuusk: Chemical composition of leaves from spectral measurements is [an] overlap area.

[An optical classification exists based on pigments. Is it as discriminating as the optical classification for algae in water quality modelling and measurement?]

Tiit Nilson: The ground [model] has plant communities involving spatial distributions and patterns which depend on scale. At small scales they may be regular and at large scales clumped. Also, the mutual influences of plants are important but rarely used in models. [Tiit suggested that these relationships would help the over-parameterised models.]

DLBJ: In ecology there are a range of models for succession called 'Gap Models' which are based on an effectively continuous canopy with 'holes'. These should be able to be modelled and used to interpret broad scale images. The individual trees are not actually considered.

Xiang Yueqin: It is important to develop descriptions of structure of the different types of crop such as wheat and corn. We need to work out how to scale structure. There is a problem in measurement at points due to different types, times of planting etc. Need to characterise the variance for agricultural applications.

Bernard Pinty: Connecting radiation with ecology. For example, with LAI it has been mostly done from spectral data. There is [apparently] no need for angular data. But what is the error in LAI? We can get LAI by inversion [of BRDF] but in the end this will only reduce error which may not be very interesting to the end users. We need to develop more [unique outputs]. Eg LAI+Structure+... For combined wavelength we have the same [structural] parameters, the same state variables so there is a lot more information but a more difficult inference.

DLBJ: Sophisticated scene and measurement models for remote sensing have often had to deliver simple products for less sophisticated biophysical models - eg SEB. But this is changing. The demands from modellers are becoming more sophisticated and spatial variation in CO_2, water and energy fluxes are being tackled by modellers. Demands for better products will come. We must anticipate these requests for structural data and have the answers ready.

Wolfgang Wanner: About the "gap". Remote sensing provides a huge knowledge [base] about the Earth's vegetation and spatial structure. So maybe RS can help extend ecologists thinking to scales they cannot reach with plot data. For example, a new LC classification based on BRDF and the way large areas green up etc.

Phillip Lewis: Remotely sensed information may often be at the wrong scale. Ecologists often need fine scale information.

Don Deering: Scale is a problem. Now ecologists are interested in detailed information such as process studies, stomatal closure for CO_2 etc.

[Why is everyone forgetting airborne data? Multi-spectral, multi-angle data with pixels < 1 metre is no problem!]

Sig Gerstl: Why do we limit ourselves? We should be extending the ecologists point of view. This is the "Pretty Picture" syndrome. We should now be extending the view using polarisation and detecting stress at a global scale. First signs of stress are not spectral but wilting - structural changes.

Alfred Chang: Microwave may be more sensitive to such stress. Physics unites all our science. The same equations but different approximations. We need to study detection efficiency.

Juhan Ross: Ecologists cannot help us. We need to educate ourselves as to what is needed and how to get it. [We must be both Hunter and Dog].

Don Deering: Do we need any more models?

DLBJ: Maybe we have enough models and what we really need are some standards?

Sig Gerstl: We need a 'super-model' of the standard models structured by application.

Bernard Pinty: Maybe we need more data. It is too early for standards.

Don Deering: We are not focussed clearly on a product. LAI at a global scale has a focus which BRDF does not have yet. Even then different models are needed for different areas.

4.2.2 Tools for Measurement of Properties & Structure

Don Deering: Need to make use of the forward scattered light to increase spectral information.

[Maybe it is almost mandatory to measure reflectance and transmittance of translucent materials. It is certainly the case that only measuring leaf reflectance of Australian trees misses more than half the information]

Juhan Ross: Need to add other regions of the spectrum - microwave, thermal etc. In microwave the is information about [the same] leaves, stems etc. and no cloud problem. We need medium sized goniometric apparatus for Shoot measurements and bridge the gap between leaf and canopy. This could use a laser beam. Maybe this would cost about $300K.

Prof. Kawata: Polarised light is important now that scanning polarised sensors are becoming available. Need ground and vegetation measurements to support POLDER.

Shunlin Liang: Canopy polarisation is 2-3% but soils polarise to 10-15% so may be more important than vegetation as an opportunity for POLDER.

4.2.3 Radiation Measurement Models & Inversion

Juhan Ross: For architecture, the use of fractals and L-Systems should be increased.

Shunlin Liang: Can BRDF help in remote sensing of water and soils?

DLBJ: In remote sensing of water the angular distribution of the emerging radiation field is highly indicative of water properties - especially in more turbid waters. Clumps of algae or other particles have a strong effect known as the 'Packet' effect in water literature.

Xu Xiru: Need to use thermal infrared data. The question is how to use it? Need Effective Emissivity (thermal BRDF) models [the models need to be effective as well!]. This is significant in CO_2 flux.

Juhan Ross: Need to connect TIR data to the heat balance and surface energy balance.

4.2.5 Infrastructure Issues

Juhan Ross: Next meeting we should invite microwave specialist[s].

Alan Strahler: Lets invite water people to the next meeting.

Don Deering: Being pragmatic - lets get people from the ecological community here to talk about structure - perhaps a “Tutorial”.

Don Deering: There is an email based “Plant Canopy Network”. Do we want to develop an internet network? May need special funding for someone to manage it. Can start with a User Group on the internet.

[The issues raised are clearly ones we must cooperate to resolve. We all need to consider the end users and ‘markets’ as a common area to develop and we must all display the quality we know our work can provide. When the demand is there we can all compete as to who can meet it best or most efficiently or for the lowest cost - but until it exists our competition is probably destructive. The development of a network for the BRDF community is a very important step and regular meetings are an equally important step. A lot of ground was covered in this Meeting and quite a lot was turned over as well. I look forward to the next.]

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OPENING SESSION
Monday, September 16
Chairman: Guo Huadong, IRSA, CAS, Beijing, China.

Welcome:
Xu Guanhua, Alan H. Strahler, Chen Shupeng, Don W. Deering, Qin Dahe.

Keynote Addresses:

PRESENT STATUS AND PERSPECTIVES OF REMOTE SENSING OF VEGETATION.
Juhan Ross, Tartu Observatory, Teravere, Estonia.

OVERVIEW AND HIGHLIGHT OF KEY ISSUES.
Alan H. Strahler, Boston University, Boston, USA.

SESSION I: MEASUREMENT
Monday, September 16
Chair: **Xu Xiru**, RS&GIS Institute, Peking University, China.

[1-1] BIDIRECTIONAL REFLECTANCE CHARACTERIZATIONS FOR A VARIETY EARTH'S LAND SURFACE COVERS.
Don. W. Deering, NASA/GSFC, Greenbelt, USA.

[1-2] A MEASUREMENT CONCEPT FOR HOT SPOT BRDFs FROM SPACE.
Siegfried A. W. Gerstl, Los Alamos National Lab., Los Alamos, USA.

SESSION I (Continued): MEASUREMENT
Monday, September 16
Chair: **David L B Jupp**, CSIRO Earth Observation Centre, Canberra ACT, Australia.

[1-4] RADIATIVE TRANSFER IN CONIFEROUS TREES.
Juhan Ross and M. Sulev, Tartu Observatory, EE2444 Teravere, Estonia.

[1-5] MULTIANGLE OBSERVATIONS OF DIRECTIONAL REFLECTANCE OF SNOW FIELD.
Alfred T. C. Chang, NASA/GSFC, Greenbelt, USA.

[1-6] THE BRDFs OF LAND SURFACES ESTIMATED BY THE AIRBORNE POLDER DATA.
Yoshiyuki Kawata, K. Takemata and T. Yonekura, Kanazawa Institute of Technology, Kanazawa, Japan.

[1-7] DIAGNOSTIC ASSESSMENTS OF PLANT CONDITIONS USING MULTIANGULAR REMOTE SENSING MEASUREMENTS AND BRDF MODELS.
Qi Jiaguo, Paul Pinter Jr., T. Clarke, and Susan Moran, USDA- ARS Water Conservation Laboratory, Phoenix, Arizona, USA.

[1-8] THE NON-LAMBERTIAN PROBLEM IN THE DYNAMIC MONITORING OF VEGETATION BY NOAA-AVHRR.
Xu Xiru, Li Bing, Liu Qinhuo, Peking University, Beijing, China.

[1-9] THE EUROPEAN GONIOMETRIC OBSERVATORY.
Michel M. Verstraete, EU Joint Research Centre, ISPRA, Italy.

[1-10] THE REFLECTION AND TRANSMISSION CHARACTERISTICS OF HEALTHY GREEN LEAVES *IN VIVO*.
Zhang Hong, Zhu Qijiang, Beijing Normal University, Beijing, China.

[1-11] MEASUREMENTS OF RADIATION TRANSMITTANCE AND REFLECTANCE OF DISCONTINUOUS CANOPIES.
Xiang Yueqin, Zhou Yunhua, Institute of Geography, CAS, Beijing , China; Wang Jindi, Liu Yi, IRSA, CAS, Beijing China; Zhu Qijiang, Beijing Normal University, Beijing, China.

[1-12] INDIRECT METHODS FOR MEASURING CANOPY STRUCTURE AND THEIR VALIDATION.
Wang Jindi, Li Xiaowen, IRSA, CAS, Beijing , China; Xiang Yueqin, Institute of Geography, Beijing, China, Alan H. Strahler, BU, Boston, USA.

SESSION II: MODELS, VALIDATION, INVERSION
Tuesday, September 17
Chair: **Juhan Ross**, Tartu Observatory, EE2444 Teravere, Estonia.

[2-1] ADVANCED MODELS FOR MULTIANGULAR REMOTE SENSING DATA INTERPRETATION.
Bernard Pinty, Michel M. Verstraete, Ola Engelsen, Nadine Gobron, John V. Martonchik, Space Apps. Inst. ,EC-JRC, ISPRA, Italy.

[2-2] A BRDF MODEL FOR FORESTS.
Tiit Nilson, Tartu Observatory, EE2444 Teravere, Estonia.

[2-3] TOPOGRAPHIC EFFECTS ON SURFACE BIDIRECTIONAL REFLECTANCE SCALING.
Shunlin Liang, Ralph Dubayah and Dave Shirey, University of Maryland, USA; Phillip Lewis, Univ. College London, UK.

[2-4] MODELLING DIRECTIONAL VARIANCE AND VARIOGRAMS USING GEO- OPTICAL MODELS.
David L B Jupp, CSIRO Earth Observation Centre, Canberra ACT, Australia.

[2-5] SHORTWAVE RADIATION TRANSFER OF CONIFER BOREAL FORESTS DURING BOREAS :RESULTS OF MEASUREMENT AND MODELING.
Jean-Louis Roujean, Meteo France/CNRM, Toulouse, France.

[2-6] A MODIFIED GEOMETRIC OPTICAL RADIATIVE TRANSFER APPROACH FOR BIDIRECTIONAL REFLECTANCE OF DISCONTINUOUS PLANT CANOPY.
Ni Weijin, Li Xiaowen, Curtis E. Woodcock and Alan H. Strahler, Boston University, Boston, USA.

[2-7] UNCERTAINTY AND SENSITIVITY MATRIX OF PARAMETERS IN INVERSION OF PHYSICAL BRDF MODEL.
Yan Guangjian, Li Xiaowen, Liu Yi, IRSA, CAS, Beijing, China.

[2-8] THE CALCULATION OF THE REFLECTANCE OF THE FOUR COMPONENTS.
Zhu Qijiang, Fan Shaohua, Zhang Hong, Zhao Liping, Beijing Normal University, Beijing, China.

[2-9] PROCESS SYSTEM OF MEASURED BIDIRECTIONAL REFLECTANCE IN CHANGCHUN LABORATORY.
Gao Feng, Nanjing Inst. of Geography and Limnology, CAS, Nanjing, China; Zhu Qijiang, Beijing Normal University, Beijing, China.

SESSION III: MODELS, VALIDATION, INVERSION, Continued
Tuesday, September 17
Chair: **Siegfried A. W. Gerstl**, Los Alamos National Lab., Los Alamos, USA.

[3-1] EVALUATION OF A 3-D RADIATIVE TRANSFER MODEL AGAINST GONIOMETER MEASUREMENTS ON AN ARTIFICIAL TARGET.
Michel M. Verstraete, Y.M. Govaerts, and Brian Hosgood, IRSA, ISPRA, Italy.

[3-2] RETRIEVAL OF BIDIRECTIONAL REFLECTANCE FACTORS AND DIRECTIONAL-HEMISPHERICAL REFLECTANCES USING SPACE-BASED AND AIRBORNE MULTI-ANGLE OBSERVATIONS.
John V. Martonchik, California Institute of Technology, Pasadena, USA.

[3-3] GLOBAL BRDF AND ALBEDO FROM THE EOS MODIS AND MISR SENSORS.
Wolfgang Wanner, Alan H. Strahler, Hu Baoxin, Phillip Lewis, Li Xiaowen, and J.-P. Muller, Boston University, Boston, USA.

[3-4] ENHANCED DISCRIMINATION OF BOREAL FOREST COVERS USING DIRECTIONAL SIGNATURES MEASURED BY THE AIRBORNE POLDER INSTRUMENT.
Marc Le Roy, P. Bicheron and O. Hautecoeur, CESBIO, Toulouse, France.

[3-5] AVHRR BRDF INVERSION FOR AFRICA.
Phillip Lewis and E. Vives Ruiz de Lope, Univ. College London, London, UK.

[3-6] RETRIEVAL OF LAND-SURFACE PARAMETERS FOR METEOROLOGICAL MODELS FROM MULTIANGULAR OPTICAL MEASUREMENTS.
Jean-Louis Roujean, Meteo France/CNRM, Toulouse, France.

[3-8] MONITORING OF LAI AND CHLOROPHYLL CONTENT BY THE INVERSION OF A CR ANALYTICAL MODEL.
Andres Kuusk, Tartu Observatory, EE2444 Teravere, Estonia; Zhang Renhua, Institute of Geography, Chinese Academy of Sciences, Beijing, China.

[3-9] AN INVERTING APPROACH OF BRDF FOR WHEAT IN NORTH CHINA USING NOAA-AVHRR IMAGE.
Zhang Renhua, Chen Gang, Institute of Geography, CAS, Beijing, China; Andres Kuusk, Tartu Observatory, EE2444 Teravere, Estonia; Alan H. Strahler, Boston University, Boston, USA; Li Xiaowen, IRSA, CAS, Beijing, China.

SESSION IV: ATMOSPHERE-SURFACE BRDF INTERACTION
Wednesday, September 18
Chair: **Don W. Deering**, NASA/GSFC, Greenbelt, USA.

[4-1] USING BRDFs FOR ACCURATE ALBEDO CALCULATIONS AND ADJACENCY EFFECT CORRECTIONS.

Christopher C. Borel and Siegfried A. W. Gerstl, Los Alamos National Lab., Los Alamos, USA.

[4-2] THE EFFECT OF SURFACE BRDF ON ATMOSPHERIC CORRECTION.
Wolfgang Wanner, Hu Baoxin, Alan H. Strahler, Boston University, Boston, USA; Li Xiaowen, IRSA, CAS, Beijing, China.

[4-3] PROCEDURES FOR REGISTERING POLDER AIRBORNE SIMULATED MULTIANGULAR IMAGES.
Zhu Chongguang, Guo Jun, Yu Fangfang, IRSA, CAS, Beijing, China.

CLOSING SESSION
Wednesday, September 18
Chair: **Alan H. Strahler**, Boston University, Boston, USA.
Vice-Chair: **Tian Guoliang**, IRSA, CAS, Beijing, China.

Subject: Key Issues in Future BRDF and Related Research.