MAIN CONCLUSIONS OF THE ACTIVITY OF THE WORKING GROUP VII.3

BETWEEN 1984 and 1988

Gérard GUYOT

INRA, Bioclimatologie - BP 91 - 84140 MONTFAVET FRANCE

Abstract

The working group VII.3 "Spectral Signatures of Objects" organized an International Colloquium at Les Arcs (France, 16-20 December 1985) and jointly with Working Group VII.2 (Microwave data, Chairman N. LANNELONGUE), an International Colloquium at Aussois (France, 18-22 January 1988). These two colloquia were research meetings designed to present results of actual work from ultraviolet to microwaves and to define future directions.

A short analysis of the main contributions of the two colloquia is presented. These dealt with new techniques, which are or will be used in remote sensing (high spectral and spatial resolution, laser active remote sensing, passive and active microwaves), and modeling of spectral response of natural surfaces in the whole electromagnetic spectrum.

Introduction

The Working Group VII.3 of the Commission VII of the International Society for Photogrammetry and Remote Sensing organized two specialized International Colloquia on Spectral Signatures of Objects in Remote Sensing between 1984 and 1988. These colloquia followed the two first organized between 1981 and 1984. The first one took place at Les Arcs (France, 16-20 December 1985) and the second one, organized jointly with Working Group VII.2 (Microwaves data, Chairman N. LANNELONGUE), took place at Aussois (France, 18-22 January 1988).

The aim of this paper is to present the main contributions of these two colloquia and which concern the whole electromagnetic spectrum from ultraviolet to microwaves.

I. Aim and Organization of the Colloquia

1.1. Aim of the Colloquia

The aim of the colloquia was to arrange a discussion on the methods of interpretation of radiometric data (acquired on the ground level or aboard aircraft or satellites). All spectral domains were considered and all application fields of remote sensing were represented : agriculture, forestry, geology, hydrology, oceanography, glaciology...

In view of the development of research performed in the microwave domain and the complementarity of the scientific approaches of Working Group 2 and 3, the last colloquium was organized jointly by the two groups.

In the two colloquia the diversity of participants has permitted animated and constructive exchanges. The number of participants was around 230 for the two meetings and they represented about 25 different countries. The number of papers presented has increased regularly from the first meeting (54 at Avignon, 8-11 September 1981) to the last ones (104 at Les Arcs and 114 at Aussois). This shows that this type of specialized meeting corresponds to a real need and concerns the whole international scientific community.

1.2. Organization of the Colloquia

In each colloquium, the contributing papers were presented during 4 days in plenary and poster sessions. The morning of the fifth day was reserved for the presentation of the conclusions on the different themes selected for each of the colloquia.

Plenary sessions were reserved for a limited number of review papers or papers presenting new research orientations. Poster sessions were reserved for more specialized papers.

Generally, each day included two plenary sessions (one in the morning and one in the afternoon) followed by two poster sessions. In order to facilitate discussions among participants, the presentations were organized in the different sessions in order to have at least 5 papers dealing with the same subject.

At Les Arcs, the selected themes were the followings :

- Promess and Toscane T simulation campaigns (ERS1 simulation campaigns over the North Sea),
- Modeling in the microwave region and over land,
- Modeling in the optical domain,
- New passive spectral methods,
- New active spectral methods,
- Sensor and data calibration,
- Spectral characterization of objects.

Moreover a round table was organized on harmonization and standardization of measurements.

At Aussois, the selected themes were quite different :

- Microwave signature of vegetation,
- Microwave interaction with the sea surface,
- Laser active remote sensing,
- Emission of natural surfaces in the thermal infrared,
- High spectral resolution,
- Models of spectral response of natural surfaces,
- Spectral characterization of objects.

Moreover two plenary sessions were devoted to presentations on :

- Large scientific remote sensing programmes,
- Projects and future systems.

These sessions were followed by round table discussions in the evening on the same subjects.

II. General conclusions

The conclusions of the two colloquia can be arranged as a function of different themes discussed in one or both of them.

2.1. Microwave interaction with sea surface

From the presentations at Les Arcs and Aussois, the following research objectives can be suggested.

- To improve both the hydrodynamic and the electromagnetic backscattering models. The improvement appears of crucial importance while considering interactions at high wind speed : the very complicated geometrical structure of the water surface as well as the presence of specific phenomena, such as the wave breaking would severely limit the validity of actual models.

- To encourage the development of sea surface data collection methods using buyos, research vessels and aircraft.

- To develop theoretical and experimental investigations of radar backscattering mechanisms to assess the impact of secondary influences (swell, wave modulation, temperature) on models.

- To improve the SAR capability for accurately imaging ocean waves.

2.2. Microwave signature of land surfaces

At Aussois, new developments were presented on passive microwaves. In spite of their low spatial resolution the passive radiometers can be successfully used in estimating :

- The soil moisture (frequency lower than 6 GHz),
- The vegetation index on a world wide scale (on some km^2),
- The water vapour content of the atmosphere which is a basic reguirement for the radiometric correction in the whole spectral range.

In the domain of active microwaves an effort is made to have more detailed analysis of the observed phenomena for a better definition of the validity domains of models (moisture profile of the soil surface layer, crop geometry, coherent polarization...). In geology, an original approach was presented. It is based on the utilisation of the radiometry in order to improve the definition of the observation conditions adapted to each theme.

The results presented in both colloquia showed the necessity to increase :

- The calibration and intercalibration of the instruments used,
- The number of plant canopies on which the models are adjusted,
- The spectral signatures measurements in passive radiometry.

2.3. Laser active remote sensing

With this technique there appears to be a great new potential for acquiring additional information about the surface in visible and infrared by controlling illumination, direction polarization, wavelength, etc. These capabilities to not exist or are limited when using passive techniques. The ability to look at target fluorescence in addition to elastic and Raman

scattering should yield significant new information about the surface. Applications areas include water quality and photosynthesis of plant canopies for the UV or blue system and rock, soil, mineral (geology) discrimination using the thermal IR part of the spectrum. In thermal infrared a promising technique is also proposed : the combination of passive and active measurements to determine the emissivity of natural surfaces.

The fluorescence techniques can be used in two different ways : the determination of the intensity of the fluorescence at given wavelength (685 and 735 nm for chlorophyll fluorescence) or the measurement of the decay time of the fluorescence. This second technique to be a promising tool for discriminating crude oil at sea surface or to analyse the photosynthetic activity of a plant canopy.

2.4. Emission of natural surfaces in thermal infrared

Presented papers in both colloquia stressed some important points which must be developed in the near future ;

- The atmospheric correction methods, in order to reconstruct the temperature and humidity profiles from remotely sensed data coupled with atmospheric multilayer models.

- The determination of the surface emissivity either from direct measurements or from measurements in different spectral bands (use of high spectral resolution).

- The utilization of differential measurements between surfaces having the same nature in order to improve the accuracy of acquired data and to avoid the use of complex correction models.

- The coupling of thermal measurements with measurements performed in other spectral domains (particularly : passive microwaves) in order to have a better comprehension of physical parameters which are involved.

- The significance of the radiative temperature measured on a pinpoint or integrated on large surface (some km^2) in order to introduce this data in flux calculation models.

2.5. High spectral resolution

Most of the work reported in both colloquia was done in the visible near infrared and short wavelength infrared regions of the spectrum and a large number of domains of application were covered : atmospheric science, botany, geology and oceanography and inland waters. The last colloquium with 20 papers on this theme gave a good survey of actual status of research in progress.

The main contributions in this domain are summarized below.

- In the atmospheric science good modelling efforts are in progress to develop techniques for extracting information from remotely sensed spectra on atmospheric characteristics at the time of data acquisition. This information would then be put into the appropriate model to correct for the atmospheric effects on surface reflectance.

- For the studies of plant canopies, two domains are more specificly investigated : the red edge (0.6-0.8 µm) and the middle infrared (1.5-1.7 µm). Spectral shifts of 10 to 30 nm of the inflection point of the reflectance between red and near-infrared are observed as a function of the status of plants and plant canopies. Results presented at Aussois indicate that the shift can be detected utilizing only a few well-placed narrow spectral bands (2 to 5 nm) over this region of the spectrum. In the region between 1.5 and 1.7 µm results presented exhibit a strong correlation between spectral reflectance and canopy starch and lignin contents.

The utility to geology of high spectral resolution in the 2.0 to 2.5 m region has long been known from laboratory measurements and demonstrated through the use of several airborne spectroradiometers and an imaging spectrometer. Actually the research is oriented towards the visible and near infrared portion of the spectrum. The high spectral resolution offers potential identification of rocks such as carbonatites and it for is also conjectured to be of value in studying surface weathering of rocks.

On water surfaces high resolution spectral measurements have shown the possibility to determine the strength of the fluorescence peak at 685 nm arrising from chlorophyll of near surface phytoplankton.

From the work presented the following recommandations can be proposed :

- To conduct more high spectral resolution imaging experiments from the air, in conjunction with high spectral resolution studies on the ground, of the various earth surface targets and the atmosphere.

- In the atmospheric sciences to conduct more field experiments with spectrometers for characterizing the atmospheric effects on ground reflectance and to advance beyond the current modelling stage in developing techniques that could be routinely applied to remote sensing data to accurately correct for the atmosphere.

- In the botanical sciences, three recommandations are proposed :

  . To increase research in the 0.4-2.5 µm domain based on laboratory, field and airborne measurements,
  . To give more attention to the development of more effective and efficient information extraction algorithms that are specific to plant or canopy status,
  . To develop a better understanding of the physical processes giving rise to specific reflectance features.

- In geology, the major effort needed now is in the visible and near infrared portions of the spectrum. More imaging experiments must be conducted over natural weathered terrains in conjunctions with field work with portable spectroradiometers.

- In the water disciplines, additional work must be conducted in the area of validation of the existing physical models which are being applied to real remotely sensed data (influence of suspended sediments, high chlorophyll concentrations, subaquatic vegetation...).

2.6. Models of spectral response of natural surfaces

This part of modelling in the colloquia has increased regularly.

The presented models gave a good description of the angular, spectral and temporal effects for vegetation, snow, atmosphere.

At Aussois, four new orientations appeared :

- Introduction of new parameters which can be deduced from remotely sensed data and which enable a simplified description of the studied areas. Then three new parameters were proposed :

  . The hot spot aperture angle which depends on the geometry of a plant canopy,
  . The radiometric leaf area index which integrates the effect of the geometry of a plant canopy,
  . The index of anisotropy which can replace complex angular variables in models.

- The utilization of simplified but realistic models giving results as accurate as more sophisticated ones. But these models are only valid in a limited domain of variation of their parameters.

- An effort made to introduce remotely sensed parameters into descriptive models in order to facilitate their inversion. This approach was presented for different domains : vegetation, snow and atmosphere.

- For vegetation some approaches combine basic analysis of growth processes and global parameters which can be measured by satellites.

From the results presented in both colloquia, the following recommendations can be deduced :

- Development of models which can include the effect of :

  . The conditions of measurements,
  . The mechanism of the evolution of the analysed objects (temporal aspect),
  . The coupling with the atmosphere at the energetic and radiometric level,
  . The measuring scale.

- Simplification of models and introduction of parameters measured by satellites (integrating parameters).

- Combination of models in different spectral domains simultaneously based on deterministic and statistical approaches. A strategy must then be defined which can by-pass certain elements and go directly from a satellite measurement to an output or, as coupled systems are considered, in cutting certain couplings and in replacing them by the corresponding satellite measurement which gives the lacking information.

2.7. Sensor and data calibration

This subject was only discussed at Les Arcs. Two types of calibrations must be considered :

- The relative calibration, mainly important in statistical analyses of digital imagery and multitemporal studies for knowing change in sensor response with time.

- The absolute calibration, important in inputs as physical quantities for models (e.g. : energy budgetj), for intercomparison of different sensors, multitemporal analyses and atmospheric corrections.

For future emphasis the following suggestions can be made :

- Model sensitivity analyses are needed to know accuracies required for inputs to inversion models to get results of optimum thematic value. A first attempt was presented at Aussois in microwave and optical domain but this point needs more investigation.

- Intercomparison of radiative transfer models. Many are "approximative, some "exact". A carefully designed intercomparison should be made to see over what range of inputs their outputs appear reliable.

- Joint experiments on slected common targets. The accuracy of absolute calibration is difficult to determine. Every effort should be made to perform as many independant cheks as possible. Teams should cross-check results in joint calibration experiments. That seems preferable to a generalized standardization, which is desirable but not until the optimum method will be found.

At the Aussois meeting, these problems were discussed in the round table discussion devoted to large scientific remote sensing programs (Agrisar 86, FIFE, HAPEX-MOBILHY). Such large experiments offer the possibility to compare and to intercalibrate different methods on the same area.

2.8. Spectral characterization of objects

The importance of this subject has decreased from the first colloquium (Avignon, September 1981) to the last one. Most of the papers presented deal with visible and near infrared measurements and are application oriented.

2.9. Large scientific remote sensing programs

At the Aussois meeting the large scientific remote sensing programs were presented and discussed for the first time. The plenary papers covered the experiments : HAPEX, AGRISAR 86, FIFE and the planned Global Change Program.

From the discussions, the following recommendations were proposed for future experiments :

- To study different surface/climatic regimes, e.g. tropical and/or boreal forests. This is necessary to test the ability to extend the HAPEX and FIFE results to larger areas.

- To use different spatial scales for analysing the phenomena in order to adapt the results to different grids used in global climatic models (100 x 100 km, 400 x 400 km).

- To integrate data from different sensors, especially those planned for the future Space Station.

However, these experiments must be delayed until :

- The analysis and distillation of the existing data sets is essentially complete.
- More efficient mechanism for data management and distribution are developed.
- The primary algorithms/models to be tested in these experiments are well defined.

2.10. The future systems and projects

This subject was also discussed for the first time at the Aussois meeting. The presented papers have given a limited but representative sample of the efforts developed by several nations and agencies to prepare systems employing remote sensing technology for earth study and resource management application. Four programs were presented : MOMS-02 by the Federal Republic of Germany, the French projects presented by CNES, the projects of the European Space Agency and the United States projects presented by NASA.

The round table discussion focused on four principal subjects :

Programmatic issues in sensor and systems development

Adequate and complete basis and rationale must be provided to support remote sensing efforts that include large and expansion space borne, earth observing systems. It is necessary that the communities interested in applications and in science objectives coordinate their activities. It is also necessary that the rationale be as quantitative and as comprehensive as possible.

Limits on technology developement

There are no fundamental technological factors of consequence in the near future to limit remote sensing and auxiliary systems development. The only existing limit is due to handling technology and associated distribution infrastructures ; the other limit is budgetary constraints.

Technologies in the next 10-20 years

Spectral imaging systems should have a key importance. However, because of data handling challenges a good strategy could be to have the spectral imaging capability associated with pointable, modest to narrow swath width (10-50 km) and band selection. With the capability of budget and band selection the data rate could be strongly reduced.

Spacecraft size and complexity

Studies must be developed to optimize the systems. It seems that the optimum and practical size for earth-observing system may have been exceeded in some existing concepts. More thought and effort is needed to define smaller, better distributed but coherent earth observing systems.

III. Recommendations

In view of the work accomplished in the framework of the Working Group VII." during the last 4 years, the following recommendations can be made :

3.1. To continue to develop studies on modeling

Three different orientations can be proposed :

- To continue to develop simplified but operational models. A strategy must be defined in which different models are used simultaneously.

- To continue to develop descriptive models, particularly in active and passive microwaves. These models are essential to understand the different physical mechanisms involved and to determine their relative weight.

- To develop models adapted to new technologies such as high spectral resolution, chlorophyll fluorescence...

3.2. To encourage research on new remote sensing domains

Three domains need to be investigated in more depth :

- The passive microwaves which give complementary information for monitoring plant canopies and for determining the energy balance of the earth surface.

- The high spectral resolution in which two application domains in particular, must be more thoroughly investigated :
  . Vegetation : to analyse the mecanisms of the shift of the red edge and the potential of middle infrared,
  . Geology : the major effort needed now is in the visible and near infrared part of the electromagnetic spectrum.

- The laser active remote sensing. Application areas include water quality or pollution, plant canopies stresses and geology. Two domains must be investigated :

. UV and visible domains where lasers are used to induce fluorescence. In these domains the physical phenomena involved in fluorescence must be more deeply investigated and the research must be oriented towards the analysis of the decay time of the fluorescence instead of the fluorescence intensity. These approaches could be applied either for discriminating crude oils at sea surface or the photosynthetic activity of a plant canopy.

. Thermal infrared : in this domain the lasers are used to determine the surface emissivity and the combination of active and passive measurements seems to be a promising approach.

3.3. To develop studies on the complementarity of measurements performed in different spectral domains and at different spectral scales

Some examples were presented in the two last colloquia but for the development of operational remote sensing systems it will be absolutely necessary to combine measurements obteined in different spectral domains and with different measuring instruments.

The combination of data corresponding to different spatial scales introduces a new problem on the significance of measurements performed at different spatial scales.

3.4. To standardize and harmonize the experimental methods and procedures in all of the spectral domains

The detailed analysis of interaction mechanisms of electromagnetic radiation with natural surfaces will need accurate measurements near the ground surface and also methods to characterize the studied surface. It is then of importance to have an agreement between the scientist to define :

- The calibration methods,
- The best experimental procedures,
- The minimum number of parameters which must be measured to characterize a given natural surface (plant canopy, soil, rocks, water surfaces...),
- The environmental parameters which must be considered.

3.5. To encourage the international cooperation for joint measuring campaigns focused on limited objectives

These campaigns will enable cross-calibration of the measuring methods.

Conclusion

During the 1984-1988 period the Working Group VII.3 has increased its activity compared to the 1980-1984 period. The number of participants and the number of represented countries show that the colloquia have la large international audience and correspond to a real need. For this reason, it is important to pursue this activity in the framework of ISPRS.

The last colloquium was organized by Working Group 2 (microwave data) and 3 (spectral signatures) of the Commission VII. This initiative was very very well agreed and the members of the International Scientific Committee as well as the participants have suggested that the future persons responsible of Commission VII, for the 1988-1992 period, amalgamate the two working groups into a larger one which could deal with physical measurements and signatures in any spectral domain.

References

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