MINISTÉRIO DA CIÊNCIA E TECNOLOGIA
INSTITUTO DE PESQUISAS ESPACIAIS

AUTORIZAÇÃO PARA PUBLICAÇÃO
AUTHORIZATION FOR PUBLICATION

PALAVRAS CHAVES/KEY WORDS

EARTH OBSERVING SYSTEM-EOS; HYDROLOGICAL CYCLE; WATER QUALITY; EUTROPHICATION; BIOMASS CHARACTERIZATION; DEFORESTATION/FOREST; EVAPOTRANSOIRATION; RUNOFF; REMOTE SENSING

AUTORES / AUTHORS

AUTORIZADA POR/AUTHORIZED BY

Marco Antonio Raupp
Director General

AUTOR RESPONSAVEL / RESPONSIBLE AUTHOR

Getulio Teixeira Batista

DISTRIBUIÇÃO/DISTRIBUTION

- [ ] INTERNA / INTERNAL
- [x] EXTERNA / EXTERNAL
- [ ] RESTRITA / RESTRICTED

REVISADA POR / REVISED BY

Tardin
Antonio Tebaldi Tardin

CDU/UDC: 528.835:55(811.3)

DATA / DATE: August 1988

PUBLICAÇÃO Nº / PUBLICATION NO: INPE-4673-RPE/574

ORIGEM / ORIGIN: DPA

PROJETO / PROJECT: PESERE

Nº DE PAG. / NO OF PAGES: 70

ULTIMA PAG. / LAST PAGE: C.5

VERSÃO / VERSION:

Nº DE MAPAS / NO OF MAPS:

TÍTULO/TITLE

LONG-TERM MONITORING OF THE AMAZON ECOSYSTEMS THROUGH THE EOS: FROM PATTERNS TO PROCESSES

AUTORES/AUTHORSHIP

G.T. Batista
J.V. Soares
E.M.L.M. Novo
Y.E. Shimabukuro
D.M. Valeriano
H.J.H. Kux
N.D.A. Mascarenhas
L.A.V. Dias
R. Almeida Filho
L.C.B. Molion
J.G. Tundisi

RESUMO-NOTAS/ABSTRACT-NOTES

The general objective of this proposal is to understand the land processes of the Amazonia. Three main subjects are addressed: the study of the terrestrial phase of the hydrological cycle, the study of the impact of deforestation on the hydrological balance on a yearly basis, and the study of the relationship of human occupation with water quality. MODIS, HIRIS, SAR and ESTAR data are required with proper specification for each task. These instruments will fly aboard of the Earth Observing System (Eos) plataforms. Eos is one of the major NASA missions to be carried out in close cooperation with the European Space Agency and the Japanese Science & Technology Agency with intense international participation for the scientific utilization of the data acquired. The launch of the first platform is scheduled for 1995 and, by 1997 four platforms will be in operation. The Eos is a fifteen year program. Data from other remote sensing systems are also requested for the pre-launch activities. It is anticipated that Eos will be a framework for the scientific research efforts in Amazonia.

OBSERVAÇÕES/REMARKS

Proposal submitted to NASA Announcement of Opportunity for Participation in the Earth Observing System - (NASA - A.O. nº OSSA - 1 - 88)

MINISTÉRIO DA CIÊNCIA E TECNOLOGIA
INSTITUTO DE PESQUISAS ESPACIAIS

AUTORIZAÇÃO PARA PUBLICAÇÃO
AUTHORIZATION FOR PUBLICATION

PALAVRAS CHAVES/KEY WORDS (AUTORES/AUTHORS)

EARTH OBSERVING SYSTEM-EOS; HYDROLOGICAL CYCLE; WATER QUALITY; EUTROPHICATION; BIOMASS CHARACTERIZATION; DEFORESTATION/FOREST; EVAPOTRANSOIRATION; RUNOFF; REMOTE SENSING

AUTORIZADA POR/AUTHORIZED BY

Marco Antonio Raupp
Director General

AUTOR RESPONSAVEL / RESPONSIBLE AUTHOR

Getulio Teixeira Batista

DISTRIBUIÇÃO/DISTRIBUTION

- ☐ INTERNA / INTERNAL
- ☒ EXTERNA / EXTERNAL
- ☐ RESTRITA / RESTRICTED

REVISADA POR / REVISED BY

Antonio Tebaldi Tardin

CDU/UDC

528.835:55(811.3)

DATA / DATE

August 1988

PUBLICAÇÃO Nº / PUBLICATION NO

INPE-4673-RPE/574

ORIGEM / ORIGIN

DPA

PROJETO / PROJECT

PESERE

TÍTULO/TITLE

LONG-TERM MONITORING OF THE AMAZON ECOSYSTEMS THROUGH THE EOS: FROM PATTERNS TO PROCESSES

Nº DE PAG. / NO OF PAGES	ULTIMA PAG. / LAST PAGE
70	C.5

VERSÃO / VERSION	Nº DE MAPAS / NO OF MAPS

AUTORES/AUTHORSHIP

G.T. Batista
J.V. Soares
E.M.L.M. Novo
Y.E. Shimabukuro
D.M. Valeriano
H.J.H. Kux
N.D.A. Mascarenhas
L.A.V. Dias
R. Almeida Filho
L.C.B. Molion
J.G. Tundisi

RESUMO - NOTAS / ABSTRACT - NOTES

The general objective of this proposal is to understand the land processes of the Amazonia. Three main subjects are addressed: the study of the terrestrial phase of the hydrological cycle, the study of the impact of deforestation on the hydrological balance on a yearly basis, and the study of the relationship of human occupation with water quality. MODIS, HIRIS, SAR and ESTAR data are required with proper specification for each task. These instruments will fly aboard of the Earth Observing System (Eos) plataforms. Eos is one of the major NASA missions to be carried out in close cooperation with the European Space Agency and the Japanese Science & Technology Agency with intense international participation for the scientific utilization of the data acquired. The launch of the first platform is scheduled for 1995 and, by 1997 four platforms will be in operation. The Eos is a fifteen year program Data from other remote sensing systems are also requested for the pre-launch activities. It is anticipated that Eos will be a framework for the scientific research efforts in Amazonia.

OBSERVAÇÕES / REMARKS

Proposal submitted to NASA Announcement of Opportunity for Participation in the Earth Observing System - (NASA - A.O. nº OSSA - 1 - 88)

SUMMARY

MINISTÉRIO DA CIÊNCIA E TECNOLOGIA
INSTITUTO DE PESQUISAS ESPACIAIS

LONG-TERM MONITORING OF THE AMAZON ECOSYSTEMS THROUGH THE EOS: FROM PATTERNS TO PROCESSES

A Proposal to
the National Aeronautics and Space Administration

Submitted by the

Instituto de Pesquisas Espaciais - INPE
Ministério da Ciência e Tecnologia - MCT
Av. dos Astronautas, 1758 - C.P. 515 - 12201 - São José dos Campos - SP - Brasil

Principal Investigator:

Dr. Getúlio T. Batista
INPE - C.P. 515
Instituto de Pesquisas Espaciais
12201 - São José dos Campos - SP
Brasil
Tel.: (123) 22-9977
Telex: 123-3530 INPE BR
Telefax: 123-21-8743

Co-Investigators:

Dr. J. V. Soares	INPE
Dr. E.M.L.M. Novo	INPE
Dr. Y. E. Shimabukuro	INPE
Mr. D. M. Valeriano	INPE
Dr. H.J.H. Kux	INPE
Dr. N.D.A. Mascarenhas	INPE
Dr. L.A.V. Dias	INPE
Dr. R. Almeida Filho	INPE
Dr. L.C.B. Molion	INPE
Dr. J.G. Tundisi	CRHEA/University of São Paulo

INPE PROGRAM:
Remote Sensing Basic Research Program

Authorizing Institutional Official:

Dr. Marco Antonio Raupp
Director General

June 13, 1988
Date

Reference:
The Earth Observing System
Eos, AO nº OSSA-1-88

Abstract

Amazonia has been defined as a world of vegetation and water. Its size, the dominance of forests, and hydrographic system support its outstanding importance in Earth surface processes. This proposal is an initiative of Brazilian scientists who envisage Eos as a powerful tool that will lead to the understanding of some of those processes in Amazonia in a spatial and temporal perspective. Three main subjects are addressed: the study of the terrestrial phase of the hydrologic cycle, the study of the impact of deforestation on the hydrologic balance on a yearly basis, and the study of the relationship of human occupation with water quality. The first task will be developed in a small undisturbed catchment basin where intense micrometeorological, vegetational and hydrological in situ measurements will take place. These measurements and Eos data will be utilized for the adaptation of a hydrologic cycle model for environmental conditions found in the Amazonia and related ecosystems. Inversion of this model will be attempted in order to optimize the utilization of the Eos for the study of water relations in terrestrial Amazon ecosystems. The second task will consist of an analysis of the relationship of deforestation rate with water balance of a second order tributary of the Amazon river. Deforestation rate will be assessed through Eos data and satellite data available during the pre-launch phase. The water balance variables will be derived from hydrologic and meteorologic stations records. The third task will explore selected tributaries a large Amazon reservoir with differential land use pressures in their basins. Spectral characteristics of water will be associated with physical, chemical and biological indicators of trophic level in order to support its monitoring with Eos data. This shall lead to the discrimination of natural from anthropogenic trends in the aquatic ecosystem. MODIS-N, MODIS-T, HIRIS, SAR, and ESTAR data are required with proper specification for each task. Data from other satellite remote sensing systems are also requested for the pre-launch activities. The scientists involved in this proposition consider that Eos may furnish a framework for the scientific research efforts in Amazonia and, in this sense, the present proposition is still only the first step.

LONG-TERM MONITORING OF THE AMAZON ECOSYSTEMS THROUGH THE EOS: FROM PATTERNS TO PROCESSES

1.0) PROBLEM STATEMENT AND OBJECTIVES

The Amazonia is a universe of forest and water. The Amazon region contains nearly half of Earth's tropical rain forest and is responsible for almost a fifth of the World total freshwater. This universe is still scientifically poorly understood but has already undergone important disturbances: rapid deforestation, dam building, and intensive mining activities. Those disturbances may threaten the Amazon ecosystem's equilibrium, but the scientific framework to assess those environmental impacts is still inadequate. That assessment depends on a better understanding of the links between both terrestrial (forest and soil) and aquatic (climatic and water) ecosystems. Previous studies have shown evidences of water recycling in the Amazon region, which is not neglegible in relation to total precipitation and might represent up to 50% of the water vapor generating rain in the region. Limnological studies have also proved that the principal **Ca** source for the Amazon river waters is the forest, the soluble **Ca** comes from the rain intercepted by the forest and washed through the canopy down to the ground.

The delicate balance between forest and water when broken leads to a series of short and medium-range consequences such as : 1) increase in surface runoff; 2) increase in soil erosion, and 3) increase in nutrient level in aquatic ecosystems. Long-term changes however, are not predictable since they are dependent on feedback processes which are not yet understood in such a complex environment.

It is known that 90% of the Amazon rain forest is formed of "terra firme" (never flooded) forest areas. These areas have been used to expand the agriculture in the region. About 2-3 million ha of forest are now being converted annually into agricultural production (pasture, coffee, annual crops, cacao, rubber, etc.) (1).

Research has greatly increased during the past 15 years in an effort to find adequate answers raised by the ecologists and to help the government policy for Amazonia occupation. The remaining problem is to determine what changes might occur and to what degree these changes would influence the water cycle and other biogeochemical cycles both in the region itself and in adjacent areas as a result of the Amazon occupancy.

Research to answer such questions can be subdivided into several categories:

a) water and energy balance on a microclimate scale;
b) regional energy balance;
c) water balance in representative hydrographic basins;
d) water balance on a regional level (Amazon Basin); and
e) biogeochemical cycles on a basin or regional scales.

Several projects have attempted to provide answers to these questions (1):

i) Biogeochemistry of the carbon cycle: to quantify the carbon exported from the Amazon basin and the changes suffered by organic compounds during transportation; coordinated by the University of Washington (UW), Instituto Nacional de Pesquisas da Amazônia (INPA), and Centro de Energia Nuclear na Agricultura (CENA). This project started in 1982.

ii) Micrometeorology Experiment in the Amazon Region : to quantify micrometeorological and plant physiological measures of energy and vapor exchange between the tropical forest and the atmosphere as a basis for studies and modeling of the surface atmospheric layer; coordinated by the British Institute of Hydrology, Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Instituto Nacional de Pesquisas da Amazonia (INPA) and Instituto de Pesquisas Espaciais (INPE) (2).

Researchers in Brazil and abroad comprising the Amazon Basin have written over 100 papers . Among these papers are those organized in "The Geophysiology of Amazonia" (3). There is an overview on climate, natural vegetation, soils, micrometeoroly, hydrological cycle, and modeling effects of vegetation on climate (see for example (4),(5),(6),(7), and (8)). Of particular importance was an essay to relate the forest and the hydrological cycle for the Amazon Basin (1). Nevertheless, the basic hydrological data are so inadequate that any conclusion concerning the hydrologic cycle must be suspect. This inadequacy is a problem for the meteorological and hydrological services of the countries concerned. Lack of funds, difficulty of access, problems of making the basic measurements in a hostile environnment, questions of representativeness and extrapolation, lack of staff, and others difficulties are only too well known to the agencies involved. Use of remote sensing techniques provides some means of overcoming not only the basic lack of data but also the difficulties and the EOS program with its multisensors capability is expected to improve this task. However, remote sensing by itself will not provide the complete answer to such a complex problem as the hydrologic cycle of the Amazonia. To model the energy and water fluxes, several additional ground measurements collected in a compatible manner will be necessary.

It is well known that the components of the hydrologic cycle are so strongly coupled to the mechanisms of atmospheric circulation and climate cycle that none of these can be meaningfully studied independently. In this context, the scientific questions to be addressed by Eos require an improved understanding of the global hydrologic cycle; for the Amazon region, remote sensing is a unique way to overcome the lack of basic hydrological data. Considering that most of the Amazonia are "terra firme" areas, a local survey (small basin) could be the basis for understanding the regional hydrologic cycle (large basins like Tocantins, Araguaia, Xingu, etc.). Repeating this study on a yearly basis in a regional scale could provide means for understanding climatic changes.

The following objectives were established for this study:

1) to model the land phase of the hydrological cycle in an undisturbed hydrographic basin;

2) to model the relationship between deforestation rates and the hydrological cycle on a yearly basis for a large basin;

3) to model the relationship between nutrients and sediment load and their effects on primary productivity of aquatic ecosystems: the eutrophication process.

2.0) MODELING THE LAND PHASE OF THE HYDROLOGICAL CYCLE IN AN UNDISTURBED AREA.

a) Scientific rationale

The water balance at the surface/atmosphere interface is directly coupled with the energy balance by the evaporative fluxes. These, by their turn, are very influenced by the vegetative cover, which in Amazonia is one of the most complex ones in terms of biomass, amount, and structure: the tropical rain forest.

Micrometeorological measurements on the energy partition in the Amazon forest using an eddy correlation equipment in a site with climate representative of the region was carried out by (2). The authors concluded that the daily total evaporation for a transpiring canopy accounts for 70% of the available radiant energy and is two thirds of continental estimates of potential evapotranspiration. These results were used to provide an initial calibration of a simple, physically based model of daily evaporation for Amazon rain forest.

The water balance in an experimental basin (area of 25 km2) in the Amazon region was determined for the first time in a forest reserve of INPA located 60 km north of Manaus ((9) and (10)). The program was established through collaboration between INPA and CENA/USP and was supported by the World Meteorological Organization (WMO) and the Organization of American States (OAS). The water balance was measured using pluviometers placed above the tree tops and randomly at the ground level. Stemflow measurements were also made. Detailed descriptions of the methodology used and measurements taken can be seen in the references above ((9) and (10)). It was shown that interception depends on rain intensity, varying from 35% to 13%, the average being 22%. Biomass structure was not taken into account for interception modeling. Heavy rains have little influence on stemflow with an average about 0.3%. Throughfall varies with rain intensity, from 65% to 87%, with an average of 78%. For a two-year period, streams ("igarapés") drained off 26% of the total precipitation. Transpiration removed about 48.5%, and evaporation of water intercepted by the leaves removed about 26%. The authors did not relate the water balance for shorter intervals of time (weekly or monthly) in their "black box" hydrologic system.

Water storage in forest stands by rain interception may range from 1 - 3 mm ((11) and (12)) . This value is conditioned by the canopy architecture which in tropical forests features great horizontal variability due to their treefall dynamic ((13),(14),(15),and (16).

The physical basis of remote sensing depends on the inference of those land surface characteristics that could be measured by the emitted or reflected electromagnetic radiation coming from the Earth. The hydrologically relevant parameters that have been studied using this approach include: surface temperature, evapotranspiration, soil moisture, precipitation, and components of the radiation balance ((17),(18),(19),(20),(21),(22),(23), and (24)).

Models that help scientists to understand the hydrologic cycle, require among others, the knowledge of vegetation, surface features, land use, soil conditions, and meteorological information over extended regions, that have different physical and environmental characteristics.

Information about the vegetation cover that are relevant to modeling the hydrologic cycle and are potentially obtainable by remote sensing means are related to three main aspects. The first one is derived from the qualitative content of the remote sensing data which allows identification of forest type ((25),(26) and (27)).

The level of detail of the classification depends on the characteristics of the vegetation cover and the specifications of the utilized sensor system (28). Eos will provide a multi approach facility which shall permit the identification of finely discriminated vegetation units. This information will be useful for the spatial generalization of the measurements that will be taken at specific sites.

The second aspect is the biomass structure of the forest cover which is a quantitative information potentially derived from remotely sensed data ((29),(30),(31),(32) and (33)). Leaf biomass and wood biomass, their horizontal pattern and vertical distribution have the possibility of being determined by remote sensing, specially through synergetic utilization of multisource observations combining the detection of reflected, emitted, and backscattered radiation.

The third aspect, also of quantitative nature, is the physiological condition of the forest cover, mainly its water status and related subjects such as leaf water content, phenological stage and plant stress ((34),(35),(36) and (8)).

Besides that, these data are required at frequent time intervals, in order to track critical parameters that control the cycle. Over the past 6-7 years a great progress has been done concerning the use of remote sensing techniques, applied to soil moisture and evapotranspiration studies ((37),(18),and (38)). It is important to keep in mind that these techniques cannot measure quantities as well as those used to obtain in situ data. Nevertheless they could perform measurements over large and often inaccessible areas as the Amazon region. An extensive overview on the compatibility of present hydrologic models with remotely sensed data is done by (39).

In the Amazon region ,some of the important hydrologic models parameters directly observable via remote sensing (mainly radar with its all weather capability) are land use and basin characteristics such as channel geometry and slope information, and areal extent of standing water. Soil moisture and vegetation moisture content are important terrestrial conditions that affect the terrestrial water balance. There is strong evidence that these land state variables may be measured directly from radar data because of the sensitivity of radar backscatter. Although others factors such as surface roughness and vegetation cover also affect the radar backscatter, changes in the dieletric constant of surface materials strongly modulate SAR image intensity .

The temporal behavior of the hydrologic process is another extremely important observational parameter. The EOS program has the potential for making frequent measurements over long periods to develop an understanding of the temporal behavior of hydrologic processes. The land phase of the terrestrial water balance can be described as:

$$P(t) = Q(t) + ET(t) \pm \Delta GW(t) \pm \Delta S(t) \pm \Delta SM(t)$$

where P=precipitation; Q=runoff; ET=evapotranspiration; ΔGW=change in ground water; ΔS=change in storage as in lakes, plant moisture, etc.; ΔSM=change in soil moisture; and t=time. P,Q, and ET are usually considered fluxes whereas GW,S and SM may be considered storages or system states at a given time (t).

Historically, hydrologists have modeled the hydrologic system as a "black box" using only input data (e.g., rainfall and potential evaporation) to produce the output hydrograph. Comprehensive hydrologic models such as the Standford IV, Model conceptually subdivides the rainfall-runoff process into a number of physical processes. However, from a system point of view, this refined model was still essentially not internally defined because there were no provisions for monitoring or measuring any of the system states, although empirical equations has been used (40).

As it will be suggested bellow, SAR has the potential to measure some of these states at scales small enough to reflect the processes. Measurements of these system state variables will require new models that incorporate the new data types. Such models would structurally resemble contemporary simulation models but would be more capable of accounting for spatial variability and change. Moreover, the subprocesses algorithms (e.g. infiltration or evapotranspiration) would be designed to use remote sensing data as well as more conventional inputs.

The terrestrial water fluxes and storages in Equation 1, relevant for a tropical rain forest are summarized here following the Eos SAR instrument panel report and others.

The synergism between Eos instruments is suggested as a way for inferring these fluxes and system states.

Terrestrial Water Storages

Soil moisture--Soil moisture is the temporary subsurface storage of precipitation often limited to the zone of aeration, that approximately coincides with the root zone. Its direct measurement or inference coupled with the spatial and temporal information derived from remote sensing data may lead to entirely new types of hydrologic data or model parameters. For example, a time series of soil moisture measurements in a spatial context may depict the dynamic nature of a watershed and reveal new hydrologic characteristics of a watershed. Early attempts to measure soil moisture from satellites altitudes were reported by ((41) and (42)). The task is how to access soil moisture in a forest with a high plant density (up to 3000 stems per ha) where trees are about 35 m. Surface moisture conditions has been qualitatively inferred from NOAA polar orbiting and GOES satellite imagery ((43),(18), and (38)) ; so Eos MODIS is expected to play the same role in the IR thermal range. For a campaign called "Radar Observation of the Guyana Rain Forest" it was shown that the radar signal (C-band) is able to penetrate the forest down to the ground and the authors proposed a simple model to characterize the absorbing and backscattering properties of the forest (44).

Detention--Part of the total water in a hydrologic basin is stored in lakes, reservoirs, and wetlands. The capability to delineate standing water boundaries in forested areas has been recently demonstrated using SIR-B and aircraft SAR quad-polarization data in the polarimetry mode (45). Maximum inundation area has been determined using NIR data (such as those that could be obtained from HIRIS and MODIS) to look into plant stress; in many vegetation types inundation induces plant stress for many days after the flood peak has passed.

Ground water-- The Eos SAR data may be useful for inferring certain ground water characteristics as water recharge/discharge in complex watersheds by the measurements of changes in surface moisture; these remotely sensed data would be coupled with ancillary, topographic, and geologic data.

Vegetation Moisture Content -- The dielectric constant of water is about 80 and that of dry soil or dry biomass is about 3 or 4. Thus, the presence of water either in soil or in vegetation canopies strongly modulates radar returns. By careful selection of frequency, polarization, and incidence angles and by combining seasonal observations, SAR can potentially measure moisture of canopy by components (woody and foliar). In this context, a study on biomass structure is very important. The water-induced absorption in the middle infrared domain, available in HIRIS and MODIS systems can also be used for estimating this parameter.

Terrestrial Water Fluxes

Precipitation-- WMO requirements for rain gauge density are so far to be met in most areas of the world, including the Amazonia. Classical data show for major part of Amazonia that the climatological average rainfall pattern exhibits a marked seasonal dependence, with a monthly maximum of about 270 mm in March and a minimum of 40 mm in August. According to many authors ((46) and (47), for example) meteorological satellites can be used to estimate precipitation based on cloud type, cloud movement and vegetation index. So we can expect that various instruments of Eos operating in the visible and IR ranges could be used to accomplish this task as well . However,the Eos SAR data would be a good alternative for obtaining vegetation index in frequent cloud covered areas. At lower frequencies, SAR images would be strongly sensitive to changes in surface backscattering due to rain-induced soil moisture changes. The ESTAR data should be used as well because the brigtness temperature is responsive to the same physical parameters as radar backscatter data, although its spatial resolution is not as good as SAR's.

Evaporative Moisture Flux --Evapotranspiration quantifies a major path of water movement from land to atmosphere. Models for estimating evapotranspiration rely on the available energy, soil moisture conditions, and plant status ((48),(17),(18), and (38)). SAR, HIRIS and MODIS data could be used synergistically for inferring parameters like albedo, stomatal resistance, canopy temperature, and soil moisture. In response to a SIR-C/X-SAR annoucement of oportunity, a model to estimate evaporation rates over bare soil was proposed (49). The model is based on a two layer approach develloped by (48). In such approach the remotely sensed data is used to invert the model until calibrated soil surface moisture obtained from SIR-C SAR agrees with the model estimates of this flux. In the same way, the simulated soil surface temperature must agree with sattelite temperature from NOOA series or similar (in clear days). Hence, the evaporation rates are compared with independent estimates from automatic stations for validation. This algorithm was implemented before with good results using data from an airborne C-band scatterometer and a TIR radiometer with compatible resolution, looking at the same angle of incidence ((50) and (21)).

Runoff--Runoff depends strongly on the moisture conditions in the basin and on the drainage patterns and cannot be obtained directly from remotely sensed data. An approach to a better understanding of the runoff process could be developed using repetitive Eos SAR imaging of a dynamic watershed. The SAR response to soil moisture coupled with change detection procedures could help to identify runoff-producing areas. As far as chemical fluxes are concerned it is imperative that flow paths be clearly identified especially if the relations of chemical fluxes to pollution sources of streams and ground water supplies are to be understood. Runoff reflects the combined effects of infiltration, soil moisture storage, and ground water recharge. Although infiltration will change over the course of a rainfall event, in densely vegeteted, humid regions such as the "terra firme" Amazon forest, the infiltration capacity is expected to be high enough to absorb most storms.

It seems clear that the Eos SAR will be a very important tool to overcome the lack of classical data for hydrologic modeling for Amazonia. Due to the presence of dense forest, the Eos SAR is expected to play three important roles : 1) to monitor the vegetation moisture changes; 2) to quantify other vegetation properties which act as confusing factors in extracting canopy moisture; and 3) to monitor underlaying soil moisture and stand water changes. The shorter radar wavelengths, cross-polarization, and higher incidence angles will provide information on the vegetation canopy; the longer wavelengths, like-polarization and steeper incidence angles is expected to provide information about the underlaying soil. Change detection procedures would emphasize changes in soil moisture and vegetation properties that could be used as direct input to water balance models or as a feedback to correct model parameters.

The observational strategy recommended for the Eos SAR is to use the first years to acquire and analyse data from representative study sites, to determine the optimum instrument and viewing parameters.

b) Reseach approach and experimental plan

Considering the objective and the scientific rationale, an undisturbed hydrographic basin with an area varying from 400 to 900 km2 will be chosen. In this case a significant number of pixels will be available through Eos MODIS including the lower resolution TIR bands.

In spite of the lower resolution of Eos ESTAR data, they are expected to help to infer synoptic-temporal changes in soil and vegetation moisture. Additionally, this basin must be covered by Eos SAR in the high-resolution mode and by Eos HIRIS as well (30 km). Several candidate test sites are available specially on secondaries tributaries of the Uatumã basin, where the Balbina dam was built. However, final decision will be taken only after discussion with INPA's, ELETRONORTE's (Centrais Eletricas do Norte), and SUDAM's (Superintendencia de Desenvolvimento da Amazônia) staff to assure the logistic and the potential future occupation of the chosen site. This decision could be made by September 1988:

The strategy for the first three or four years of Eos flying, is to acquire and analyse remotely sensed data needed to investigate the surface energy and water surface balance, in the selected site. During this phase several algorithms will be developed to: 1) detect soil moisture taking into account both vegetation cover and surface roughness confusion effects, defining yet the most suitable temporal resolution, pointing geometry, frequency and polarizations, for the SAR data; 2) estimate vegetation moisture based on leaf water absorption bands using the synergism of MODIS (low spatial resolution, high revisit capability), HIRIS (high spatial and spectral resolutions), and the microwaves systems ESTAR and SAR with their high temporal resolution for the frequently cloud-covered Amazon tropical environment; 3) estimate albedo and stomatal resistance from HIRIS and MODIS; 4) obtain surface temperature from MODIS; 5) infer precipitation from SAR and ESTAR data; 6) characterize land cover, channel geometry, and slope and assess areal extent of standing water with SAR, and 7) establish a data analysis system based on a geographical information system (GIS) concept to handle the great amount of data expected in the future phase.

The approach for modeling the land phase of the hydrologic cycle in a further phase (after three or four years of Eos flying) will be based on models that could divide the rainfall-runoff process into a number of physical processes, like the STANFORD IV model (40) and the model proposed by (51),modified by the Eos SAR Instrument Panel Report to take advantage of Eos instruments sinergism. Algorithms for obtaining evapotranspiration from remotely sensed data have to be established for the Amazon forest .

The instruments and data for "in situ" measurements will include:

a) scaffolding tower - a tower with 45 m will be installed at a site selected as representative of the natural vegetation and regional climate and topography in the chosen basin. The following instrumentation will be available:

a-1) A battery-powered eddy correlation flux measuring device mentionned as Hydra. It was developed by the British Institute of Hydrology and will be operated by INPE and INPA. Measurements obtained by Hydra are evaporation, sensible heat, and momentum fluxes. The hardware components of Hydra is fully described elsewhere (2).

a-2) Automatic Weather Stations (AWS). Two stations will be used to provide hourly measurements of temperature, wet bulb depression, net radiation, and wind speed. Independent measurements of the variables found in evaporation classical formulae will be available from other micrometeorological instrumentation so intercomparison is possible. A detailed description of the instruments characteristics is done by (2).

These measurements will be registered on a microcomputer based acquisition system installed in an air-conditioned shed at the base of the tower, that will be linked on a PCD ("Data Collection Platform"), developed by INPE. In this case data will be released to INPE ground station by the Brazilian Data Collecting Satellite. Evapotranspiration obtained from these micrometeorological measurements could be used to calibrate models using remotely sensed data;

b) measurements on the principal stream - a conventional set of river gauging will be spatially placed taking into account the drainage patterns;

c) measurements on tree tops -an array of pluviometers (about 10) will be placed throughout the watershed on the top of the trees;

d) measurements on the soil surface - several pluviometers will be placed at the soil surface in two small areas with different biomass structure (estimated through Landsat or SPOT data in the pre-launching phase, and HIRIS and MODIS in the operational phase) for estimating and modeling the rainfall interception;

e) vegetation measurements - the tree synusiae of the plant communities of the areas selected for in situ micrometeorological observation will be floristically inventoried. The following biomass structure are to be measured for physionomical characterization of the forests: DBH, tree height, crown cover, volume, and shape. Parameters related to leaf biomass have to be observed two to four times a year in order to detect possible phenological rithm in the vegetation. Leaf Area Index (LAI) will be estimated through measurements of light interception after an empirical determination of the light-extinction coefficient (52). Corrections for inhomogeneous canopies will be evaluated (53). Trees selected as a function of dominant species and/or dominant tree architecture will be observed in order to indicate average physiological status of the vegetation. Stomatal resistance will be determined using porometers; leaf water content will be measured through gravimetric means, which will be followed by the determination of leaf thickness, area, and shape. Sapwood cross-sectional area will be measured for these trees (54) in order to subsidize the modeling of Radar interaction with trunks. Whenever relevant peculiar life of understory plants as palm trees and bamboos or lianas and epiphytes will be described in terms of parameters suited for this purpose.

f)others measurements - others in situ information will be acquired and organized on a specific file. It will include information on spatial variability of pedology, topography, geology,etc.

In order to have previous information from the site, concerning the data described above, collecting of the "in situ" data must begin in the early nineties, probably in 1990. It means five or seven years before all Eos Instruments will be operational. The frequency for obtaining non-automatic data (not linked on a PCD) must be as high as possible and seasonally variable. The frequency for each season will be defined later (September 1988). An effort will be made to obtain rainfall and soil moisture on a 3-day (weekly at least) basis. Additionally, seasonal intensive campaings (twice a year) will be carried out.

INPE is now beginning to build a multiparameter FM-CW scatterometer (C and X-band, HH and VV polarization, two powers of emission and capable of operating at various angles of incidence). This radar will fly on board of INPE's remote sensing aircraft (Bandeirantes EMB 110B1). A thermal infrared radiometer will be mounted together in order to have a synergism as indicated by (21) and (50). This equipment is planned to be operational in 1992. Therefore, it will be possible to test models,to verify spatial variability of backscattering properties and canopy radiometric temperature, and calibrate Eos SAR in terms of the radar cross section. An annual airborne campaign will be conducted to accomplish this task.

Satellite data needed will be described further in the overall data plan. Here, only the data concerning the first phase (first three or four years of Eos flying) will be pointed out. For Eos SAR a 3-day repetitive cycle with the same illumination geometry over a period covering at least the rainy season (December-May in Amazonia) is recommended, because soil moisture is highly variable. L, C, and X band ; HH, VV, HV, and VH polarizations; incidence angles between 30 and 50o, and 20-30m of resolution (narrow swath) are required. Simultaneous coverage with HIRIS (narrow swath), ESTAR (wide swath) and MODIS (wide swath) is also required for complementary information. In addition, a two-year repetitive cycle is required to monitor the significant (if any) long-term changes in watershed morphology. Eos SAR data required in this phase are at levels 1.7 (polarimetry, backscater curves, ratioing, radargrammetry, once a year),and level 1.5 as well. It is expected that as one begins to understand more fully the time scales of surface processes and identifying optimum channels, the number of bands and the frequency of observation will decrease.

For vegetation studies related to the hydrologic cycle modeling, it will be necessary at least four simultaneous coverage of MODIS and HIRIS in order to observe the phenological rithm in the studied vegetation throughout the year. MODIS-T and HIRIS off-nadir view could potentially complement the information obtained with the nadir sensors if, as it is very likely, the vegetation units have any difference in their bidirectional reflectance function. Radar data for the same dates will be essential for the full utilization of the synergetic facility of Eos instruments.

The Eos SAR Panel Report summarizes in the data acquisition plan the yearly average data for all disciplines assuming that the global mapping mode provides a frequent low-resolution coverage of the regimes of interest. For forest hydrology the summary indicates: time=135 minutes; 1 map; data rate/channel = 22 Mbps (assuming the high-resolution mode and the regional mapping mode); number of channels = 6; number of incidence angles = 2; repetitive cycle = 2 weeks (average), and yearly average data rate = 1.61 Mbps.

MODIS products required are at levels 1B and 2. Level 2 products required are terrestrial leaf area index 2 or 3 times a year; other vegetation indices (3 days repetitive cycle) and surface temperature (every 6 days, in the rainy season). HIRIS data suited is at 1B level (normal product). Because of cloud coverage frequency is high in the Amazonia, preliminary-look products in one spectral range (650 nm for instance) is requested.

3.0) MODELING THE RELATIONSHIP BETWEEN DEFORESTATION RATES AND THE HYDROLOGIC CYCLE ON A YEARLY BASIS FOR A LARGE BASIN

a) Scientific rationale

This section presents an overview on how related hydrologic parameters as vegetation, land cover/land use and geomorphological data, could be described within a second order Amazon river basin (10^4 to 10^5 km^2), using remote sensing techniques.

Vegetation - Different vegetation units are found in Amazonia as a function of ecological heterogeneity. These vegetation units present varying amount of biomass (1), which cause specific patterns of biogeochemical fluxes. In order to accomplish the objective of relating deforestation with hydrologic cycle, these vegetation units must be previously defined and mapped, which will be performed by synergic utilization of SAR and MODIS data, aided by commercial satellite data as ancillary information. Since deforestation rates are to be estimated, data from Eos SAR (in both regional and global mapping modes), at multi-incidence angles, at multipolarization and for all spectral bands are requested. Deforestation rates from some regions within Amazonia have been evaluated by (2) and (3) using AVHRR data. Therefore, data from MODIS-T and MODIS-N are expected to be of great value to perform the same task.

Geomorphological characteristics of river basins There are several hydrologic/geomorphologic features that could be detected by remote sensing, which are closely related to deforestation in Amazonia. Among these, the following could be pointed out: channel and slope geometry, erosion/deposition on river banks and oxbow lakes. These parameters could be inferred by MODIS and SAR data. The multi-incidence angle capability of SAR will be used to obtain digital elevation models (DEM) following for example (4) and (5) . DEMs obtained from SAR are useful to represent terrain and to estimate relief geometry, vegetation structure, and erosion potential. Changes in the variables mentioned above affect the hydrologic cycle. If deforestation rates, and erosion potential are assessed from remotely sensed data on a yearly basis and if rainfall, and runoff are measured (or estimated) from in situ measurements through hydrological and climatological stations, then evapotranspiration which is one of the main components of the hydrologic cycle, could be retrieved on a yearly basis. SAR, MODIS, and ESTAR data could be used also as input data in order to invert models to estimate cumulative evapotranspiration on a regional scale.

b) Research approach and experimental plan

A second order Amazon basin (size between 5 x 104 to 105 km2) will be selected by September 1988, by INPE's, INPA's and ELETRONORTE's staff, considering the logistical support from these institutions to obtain in situ data.

Evaluation of ancillary data- The reports and maps from RADAMBRASIL project are up to now the best source of thematic information (geology, geomorphology, vegetation, soils and potential land use) of Brazilian Amazonia at regional scale, which are a fair to good overview of these themes . Hydrological relevant information can be obtained from data available at hydrological stations and hydrographs at the Amazon river and its main tributaries.

Evaluation of previous remote sensing data Data sets from operational remote sensing satellites (TM/Landsat, SPOT, NOAA-AVHRR) will be analysed, using probability thresholding procedures, as proposed by (3) to discriminate forest from deforested areas. These inital data base will be used to test and to propose thematic classification algorithms for the identification of vegetation units and for reliable discrimination of forested and deforested areas.

Evaluation of Eos Data - SAR data in the global mapping mode (100m resolution), from L, C, and X bands, with HH, HV, VV, and VH polarizations, and incidence angles varying from 20o to 40o, will be essential for vegetation types discrimination and for monitoring of deforestation activities. SAR products are required at levels 1.6 and 1.7 in the first two years, for the development of appropriate classification algoritms. Level 2 data with the same spectral, polarization, and incidence angles specifications as above stated, will be necessary for the development of the inversion algorithms for estimation of relationship between deforestation rates and hydrological cycle parameters (third to tenth year of Eos). MODIS-N and MODIS-T data will be necessary for the validation and improvement of classes identification that will be proceeded with SAR data. MODIS products must be at levels 1A and 1B in the first phase, and at level 2 after implementation algorithms (3rd to 10th year of Eos). Two scenes a year from these instruments are requested.

4.0) MODELING THE RELATIONSHIP BETWEEN NUTRIENTS AND SEDIMENT LOADS AND ITS EFFECTS ON PRIMARY PRODUCTIVITY OF AQUATIC ECOSYSTEMS: THE EUTROPHICATION PROCESS.

A) Introduction

The Amazon is the world's largest river system. Thousands of lakes and rivers store and transport water within a drainage basin of 6.5 million Km2 (about 37% of Continental South America). The Amazon river discharge accounts for 18% of the total terrestrial freshwater drainage reaching the world oceans and has a huge influence on the geochemical budget of continental runoff (1).

This large system ,however, has been gradually changed by both indirect and direct human action. The indirect interventions are related to land use changes. Land use is a key factor in determining runoff rates. The increasing deforestation tends to break the balance in nutrient cycling through the increase in soil erosion rates ((2),(3),and (4)). The direct manipulation of the amazon river system has been accomplished by the construction of huge dams. Up to the present two large reservoirs have been installed Tucurui and Balbina. A third, Samuel, is under construction.

Tucurui submerged an area of approximately 2800 km2 along the Tocantins river, one of the main Amazon tributaries. Balbina has already flooded 2000 km2. By the end of this decade over 10 000 km2 will be flooded by new reservoirs built in the Amazon basin.

A large range of environmental impacts are expected ranging from increasing land use in the reservoirs catchment basin to changes in local climate (5). Previous studies on subtropical reservoirs (6) reported the increase in nitrogen and phosphate concentration as consequence of intensive agricultural land use. They also pointed out the importance of controlling phosphate levels to prevent eutrophication processes. A study (7) about the evolution of reservoirs in relation to human impacts, reports the eutrophication process derived from sewage and other oxygen-demanding wastes, organic chemicals, sediments, etc. That process occurs naturally during the slow aging of lakes (8) but can be accelerated by both runoff from fertilized agricultural lands and by discharge of domestic and industrial effluents. This process leads to a chain of events which ends up sometimes in a serious depletion of dissolved oxygen.

A large number of parameters have been used to express the eutrophication level (9): 1)standing crop of algae and aquatic plants; 2)amount of suspended solids; 3)chlorophyll levels; 4)number of algae blooms; 5)water transparency; 6)photosyntesis; 7)primary production ; 8)sediment composition; 9)dissolved solids; 10)conductivity; 11)nutrient concentration; 12) cation rate ((Na+K)/(Mg+Ca)).

The following stages were reported (7) in the evolution of reservoirs affected by eutrophication: 1)increase in the biomass and primary productivity of the phytoplankton; 2)decrease in the number of species; 3)decrease of the oxygen level; 4)decrease in water transparency; 5)increase in the ionic concentration; 6)increase in phosphorus; 7)increase in the rate of Cyonophyta's blooms. This chain of events, however, are dependent on both environmental factors and factors related to the reservoir type (size, volume, residence time, water level, depht).

Taking into account the variety of Amazonian water types ((10) and (45)) eutrophication rates are likely to vary from one reservoir to another. In terms of water chemistry Amazonia waters can be classified into "whitewater"; "blackwater" and "clearwater". The whitewater ecosystems are rich in nutrients whereas the blackwater ecosystems are characterized by extremely low and often unbalanced nutrient composition (1). Variable ecological responses to differing nutrient conditions have already been reported in the Curua -Una reservoir (11). It was observed that huge quantities of macrophytes developed in the reservoir area influenced by clear water rivers whereas in the nutrient-poor waters they were not found.

Changes in water type also affect the underwater light field. Sedimented-free whitewater has Secchi-depth of 30-50cm. Blackwater with organic compounds (humic and fulvic acids) has Secchi-depth between 1m and 1.5m. The spectral distribution of the light field is totally different, since humic acids absorb mainly in the short wave length range ((11) and (12)).

The variety of abiotic and biotic factors characterizing reservoir's catchment basin make it difficult to extrapolate from local ground sample to larger areas. The impact of land use changes, for instance, varies according to the biotic features of the catchment basin. So, the impact of land use changes on the eutrophication process can be assessed only with high spatial and temporal resolution. Up to the present a series of scientific problems has been raised concerning the potential change in primary productivity patterns resulting from land use changes in such mosaic of environmental patterns.

Important questions related to the tropical environment that can be addressed by the Earth Observing System are: 1)consequences of deforestation on both nutrient level and suspended sediment concentrations within a reservoir; 2)consequences of water quality changes on reservoir's primary productivity; 3)how to distinguish anthropogenic effects from fluctuating states of the aquatic ecosystem; 4) how to discriminate between short-term trends from long term changes from a time-limited record. Responses to the previous questions are only possible if sequential data are available over a large length of time, so as to register changes on system's variables. Only through a long-term research effort, the real meaning of those human actions on environmental equilibrium will be assessed. The availability of remotely sensed data at a variety of spatial, temporal and spectral resolutions such as those planned within the Earth Observing System will provide the scientific tools to give suitable answers to those questions.

B) Problem statement

The objective of this proposal is to model the impact of land use changes on the eutrophication rates of selected Amazonic reservoirs by using multistage sampling capability provided by the Earth Observing System.

To accomplish this objective the following aspects will be addressed: a)the relationship between water spectral properties and reservoirs trophic state; b)the relationship between trophic state and deforestation rates on the reservoir's catchment basin; c)discrimination between short-term changes and long-term changes in the water trophic states.

The first aspect will be addressed by using the HIRIS capability to provide high spectral and spatial resolution data which are essential to distinguish suspended inorganic and organic matter. Deforestation rates on reservoir's catchment basin on the other hand will be assessed by MODIS which will provide a timely overall picture of land use changes. The discrimination between short and long term changes will be accomplished by an adequated time sampling scheme based on both remote sensing systems and ground data collection systems.

The specific research efforts which will be performed are : 1)to develop a comprehensive ground data base with reservoir's water quality parameters including: spectrally filtered light penetration at different extinction depht; transparency, horizontal and vertical thermic structure; dissolved oxygen; alkalinity, dissolved organic and inorganic nutrients (nitrate, nitrite, ammonia; total and inorganic phosphate; reactive silicate); suspended organic and inorganic matter; chlorophyll-a concentration spatial and temporal distribution and phytoplankton primary productivity.

Water quality data have been systematically collected by the "Centrais Eletricas do Norte do Brasil" even before Tucurui reservoir filling. Figure 1 in appendix 2 presents the sampling grid used to collect water parameters at every week and at every fortnight in Tucurui reservoir and in its catchment basin. This sampling system can be expanded in order to attend some specific research tasks. The other reservoirs to be operated in Amazon region will be provided with the same data collection facilities; 2)to develop a remote sensing data base including: TM/Landsat data, spectroradiometric data, and HIRIS/MODIS DATA provided by EOS; 3)to select among the existing Eutrophication Models the most suitable for the tropical environment and to adapt it to be implemented with remote sensing data (28), 4)to empirically model the relationship between deforestation rates and eutrophication rates for varying time and space scales.

Concerning the development of such empirical models INPE/ELETRONORTE/ENGEVIX/CRHEA-USP are presently engaged in a research effort so as to study how changes in land use in two abiotically distinct sub-basins are affecting macrophyte infestation at their entrance point in the reservoir, and how force functions such as preciptation, winds and reservoir management practices interfere on that relationship.

C) Scientific Rationale

The capability to evaluate eutrophication processes on a regional scales dependent upon the availability of a data collection system which provides synoptic information. In this sense there has been many efforts in terms of applying remote sensing technology to eutrophication assessment (9). Those efforts are based on the fact that the consequences of eutrophication are changes in the optical properties of the water mass and an increase in productivity. Many of the eutrophication indicators can be assessed by remote sensing technology such as: a)chlorophyll ((13), (14), and (15)); water color (16) and (17); suspended solids ((18), (19), (20), and (21)); transparency (22) and (23) and aquatic vegetation (24).

A remote sensing trophic index has already been proposed in literature (9) as follows:

$$TI=k1\frac{1}{Trs}+k2CHrs+k3Vrs+k4Tratio+k5\,\hat{}CH+k6 \qquad (1)$$

where:

Trs=transparency(standardized value)
CHrs=chlorophyll(standardized value)
Vrs=aquatic vegetation (standardized value)
Tratio=tranparency ratio (standardized value)
^CH=chlorophyl increase (standardized value)
k(1...n)= weigthing factors

The above trophic index was defined by determining the first principal component of field and remote sensing indicators. The indicator term in the resulting linear equations represent standardized values of the corresponding indicators. This technique permits a reduction of the multidimensional nature of the problem to one dimension.

In spite of the potential of remote sensing technology for eutrophication assessment, current methodologies have had only moderate success because of the environmental dependency of retrieval algorithms (21). Applications of remote sensing methods for estimating water quality status of inland aquatic systems are still controversial. According to (25) the optical properties of a water mass are an intrincate function of the identities and concentrations of both supended and dissolved components. Causal interchanges of the roles of dependent and independent variables in the cause/effect relationships of environmental phenomena must be avoided. So before using remote sensing techniques to monitor an environmental variable, its role as indicator of other parameters should be clearly established. Freshwater masses located in temperate regions have a well defined seasonal cycle of temperature, nutrients, and underwater light field configuration; the way in which these factors are related and interact within the aquatic ecosystem and how they affect primary productivity are relatively well known (8). However in tropical areas temperature and solar radiation do not represent limiting factors to the primary productivity. Therefore any attempt to use remote sensing technology to model the eutrophication process as a function of land use changes must be preceeded by an assessment phase so as to evaluate how the existing limnological theories and data collection methodologies apply to Amazon environment (46) and (47).

a)Conventional techniques for assessing water quality status

At present the assessment of water quality and eutrophication processes are based on a composite of local observations subjected to variable degrees of accuracy (26). Many of those observations are single-point measurements limiting their spatial representativeness. Ship-based assessment of regional water quality status based on local samples can result in serious over or under estimation because of complex and rapidly changing spatial patterns. Table 1 in the Appendix 2 exemplifies the variability in the trophic state in some Brazilian reservoirs belonging to the same climatic region but located within differing drainage basins (27). Table 1 shows that any attempt to regionalize phytoplankton productivity for Sao Paulo state reservoirs based on measurements taken at specific site would imply in severe errors. Even between reservoirs belonging to the same drainage basin there are striking differences. Even in a small artificial lake such as Paranoa Lake (Brasilia -DF) internal variations in the trophic level (28) produced an overestimation of this parameter.

Satellite remote sensing of water colour could provide, at least in a first approach, the necessary insight on the optical variability of the water, making it easier to define a sampling scheme to optimize the conventional data collection.

Conventional techniques are also limited for detecting temporal changes in water quality parameters. Table 2 in Appendix 2 presents environmental data recorded in two seasonal periods: winter and summer. Table 2 also shows temporal variation in some water variables at a single station. Sometimes the variability in water quality measurements are not induced variations but natural changes in response to fluctuations on environmental factors. Also, in this aspect remote sensing data can improve the understanding of temporal changes, a key element to the discrimination between anthropogenic induced transformations and natural tranformations.

b) Remote Sensing Techniques for Water Quality Assessment

As sunlight passes down into the water body, its intensity is decreased and its spectral quality is modified according to the absorption characteristics of the various water components. Essentially the light absorption in natural waters is determined by four components: the water itself, the dissolved yellow substance (gilvin,gelbstoff), the phytoplankton and the non-living particulate matter (29). The energy detected by a sensor away from the surface is only a small fraction of the incoming energy. Figure 2 in the Appendix 2 presents the main interactions between light and the aquatic environment. The incident light is partially transmitted and partially reflected at the air/water interface. As light goes down the water column there is a loss in the radiation by both scattering and absorption. Scattering is responsible for an increase in the returning signal to the sensor. Generally speaking scattering is non-selective for particles greater than 700 nm,such as silts, clays and phytoplankton. Absorption however is highly selective. The result of scattering and absorption defines the downward attenuation coefficient, which is logarithmic in homogeneous medium and progressively monocromator. Water optical properties are generally classified as inherent and apparent (31). The inherent properties are defined by the absorption and scattering coefficients and by the volume scattering function. The apparent optical properties are those for which measurements are affected by the underwater light field, being highly susceptible to the acquisition framework. Generally speaking the apparent properties are those apt to be measured by remote sensing techniques. Among them the diffuse reflectance is one of the most important since it is responsible for the spectral variation in the water colour. The diffuse reflectance is also a function of those inherent properties. Therefore, to understand how remotely sensed water radiance is related to water inherent optical properties one should understand how changes in absorption and scattering coefficients affect water colour.

Three groups of substances are generally responsible for significant modifications of the absorbing properties of pure water: phytoplankton, nonchlorophyllous particles of terrestrial and biological origin and dissolved organic matter. The absorption related to each group of substances is expressed as the product of its concentration and the corresponding specific absorption coefficients. Each group is formed by several substances, but they are generally represented by a measurable parameter. For instance, concentrations of chlorophyll-a and pheophytin- a is generally used to indicate the phytoplankton and its immediate derivates or by-products having similar optical effects (32).

Some of the underlying assumptions for computing chlorophyll-a from water colour are: a phytoplankton absorption at 550nm is minimal; phytoplankton degradations products covary with chlorophyll-a; no red light is emitted from water; refractive index of phytoplankton is identical for all species. Those assumptions,however, are violated under some circunstances (33). The Cyanobacteria contain pigments which can absorb at 550nm, a non-absorbing hinge-point in the spectra of most phytoplankton. The degradation products from phytoplankton covary with chlorophyll-a in most of oceans case I- water (34). This relationship however, breaks during periods of intense phytoplankton growth. Both phaeopigments and gelbstoffe absorb more strongly around 4oo nm than at 440 nm. As a result their contribution to the chlorophyll-a signal is reduced during bloom conditions. In relation to the non-red ligth emission, fluorescence by chlorophyll-a can be detected if the aquatic ecosystem temporarily presents high concentrations near the surface. Besides that, different phytoplankton species present different refractive indices.

In spite of those problems several investigations have been carried out on the application of remotely sensed satellite data to determine phytoplankton primary productivity. Those investigations are based on CZCS data; thus the developed approaches are more suitable for ocean water because of the poor spatial and spectral resolution. The approaches for primary productivity estimation include calculating growth rate from temporal gradients of phytoplankton chlorophyll-a distribution using satellite for interpolating shipboard measurements of primary production per chlorophyl-a to large spatial scales (33).

Satellite data is also used to overcome the problems of sampling a spatially and temporally varying phytoplankton biomass. It is also recomended (33) the collection of environmental variables to reduce the error in the relationship between chlorophyll and productivity. Among the variables to be simultaneously monitored with water colour are: factors regulating photosynthesis (instantaneous light intensity, previous light intensity and nutrient availability).

The present algorithms for estimation of chlorophyll-a and pheophytin-a based on spectral ratios of the water-leaving upwelling radiance Lw (λ) measured from space with the CZCS have a repported accuracy of +/- 40%. The most commonly applied chlorophyll algorithm for use with CZCS data corrected for atmospheirc effect (35) is:

$$(Chl\text{-}a)=A(Rij)^{B} \quad (2)$$

where A and B are constants , and

$$Rij=Lu(i)/Lu(j)$$

where Lu (λ) is the subsurface upwelling radiance at a given wavelength i and j. The wavelengths i and j usually are 443nm and 550nm.

Studies (17) about the effect of non-water terms such as particulates and gelbgstoff on the relationship between reflectance and chlorophyll concentration were performed, using both in situ water quality measurements and remotely sensed water reflectance. Their main objctive were to develop remote sensing algorithms able to respond to regional and seasonal differences in runoff, phytoplankton size and pigment colour groups.

There is also interest (21) in the development of an algorithm able to minimize the environmental dependence of the retrieval variable. This algorithm should "minimize the dependence on the concurrent variable (eg. chlorophyll in the case of suspended sediment) and maximize the sensitivity to the retrieved parameter". The algorithm also should be insensitive to the atmospheric correction uncertainty. Algorithms such as:

$$Xc=\frac{a1\ R(443)+\ a2\ R(520)+a3\ R(550)}{R(550)} \quad (3)$$

where R is the subsurface irradiance reflectance at wavelengths 443nm, 520nm, and 550nm, and a1+a2+a3=1, are sensitive to the suspended sediment concentration, what make them less favourable to waters where correlation between suspended sediment concentration (SSC) and chlorophyill is time and space dependent. In type-2 waters with high turbidity an additional difficulty arises related to the atmospheric correction: the assumption of Lw(670)=0 does not apply for waters with high SSC making the procedures for correcting the radiance path term inaccurate. An alternative algorithm is proposed as follows:

$$\log(C)=a + b \log Xc \qquad (4)$$

where a and b are constants derived from best fit method; C is the clorophyll concentration and Xc is the retrieval variable:

$$Xc=R(520)/R(550) \qquad (5)$$

where R(520) is the remotely sensed reflectance at 520nm and R(550)is the remote sensed reflectance at 550nm.

The retrieval variable for suspended sediment concentration is:

$$Xs=(R(550)-R(670))^{a}\ (R(520)/R(550))^{b} \qquad (6)$$

The appropriate choice (21) of the best numerical values for a and b, the standard pigment concentration index R(520/R(550), tends to balance the dependence of the sediment-sensitive term (R(550)-R(670)) on chlorophyl concentration.

The improvements on satellite remotely sensed data which are required for better estimates of water chemical and biological properties (36) are summarized on table 3 in the Appendix 2.

Those improvements however are not sufficient for inland water applications. A review (37) on empirically derived relationship between SSC and remotely sensed radiance showed that most of them were derived for coastal and oceanic waters with suspended sediment concentrations ranging from 5mg/l to 80mg/l, whereas for inland waters much higher values can be measured during the rainy season(150 mg/l) owing to the increased surface runoff(38).

In satellite derived inland water reflectance, the magnitude of the atmosphere and water surface reflectance is comparable to the volume scatter from 3mg/l of suspended solids (39). So the remote sensing of low concentration of suspended solids is dependent on atmospheric and water surface scatter corrections. Recent studies (40) however suggest that some angular signatures are atmosphere invariant. In this aspect HIRIS and MODIS-T pointing capabillity will be essential to inland water studies.

Experimental works ((41),(42),and (43)) also give evidence that the use of multiviewing reflectance data can improve the estimates of suspended sedimemt concentration.

d) Research Approach and Experimental Plan

In this section the approach and experimental research design are discussed. The emphasis of the research program discussed here is to describe changes in the reservoir trophic level and their time and space dependence on deforestation rates.

1) Pre-Launch Phase

In the pre-launch phase attention will be focused on the following aspects: i)development of a trophic index amenable to remote sensing detection and monitoring; ii)modelling the relationship between the trophic index and remotely sensed water reflectance and, iii)selection of specific test sites for Eos data acquisition.

a - Development of Trophic Index

The development of a trophic index will be supported by the Centro de Recursos Hidricos e Ecologia Aplicada da Escola de Engenharia de Sao Carlos/Universidade de Sao Paulo which will provide technical expertise on the subject. This development will involve the following specific tasks:

<u>a1 - Data Inventory</u>

The primary data set to be applied in this activity has been collected by the Centro de Protecao Ambiental das Centrais Eletricas do Norte. The sampling design for water quality data collection was defined for conventional limnological data analysis. Researchs are underway so as to integrate remotely sensed data (TM/Landsat and AVHRR/NOAA) to improve the representativeness of water quality parameters. The existing data will be organized in a comprehensive data base so as to be spatially and timely compatible with the available remote sensing data. This compatibility will be essential to the development of an index amenable to remote detection. Auxiliary data related to water quality variability in time and space will also be gathered in a Geographycal Information System. Those data will include climatic variables (precipitation, temperature); hydrologic variables (surface runoff estimates in the reservoir catchment basin, water and sediment discharges from the main tributaries draining into the reservoir), soil variables (soil type, texture and chemical composition) and land use.

a2- Data Analysis

Water quality indicators as described in the previous sections will be classified taking into account the spatial water colour variability as detected by remotely sensed data. In this way the ecological significance of subtle colour changes can be assessed for different environmental frameworks which exist within the reservoir. After spatial classification, water quality parameter will be submitted to statistical analysis so as to investigate how they are interrelated in time and space. Statistical tests will be applied to the data to verify the following hypothesis: i) the relationship between water quality parameters are temporally and spatially constant; ii) water trophic state can be sistematically represented by a set of water quality parameters; iii) this set of parameters are not affected by catchment variables changes (deforestation rates; surface runoff; urbanization) in time and space.

b- Modelling the Relationship Between Water Reflectance and the Trophic Index

This activity will be supported by simultaneous radiometric and water quality data collection. Radiometric data collection will be accomplished by a field spectrometer mounted on a helicopter.

b1- Spectroradiometric data collection

The spectroradiometric data will be collected according to a sampling scheme based on the results from the trophic index definition phase. A series of experiments will be performed including: simulation of off-nadir measurements and platform height variations. These experiments will be conducted during important reservoir's ecological events such as: high and low water stages; intense surface runoff and reservoir management practices.

Spectroradiometric data will be collected in the spectral range of 400nm to 1100nm or 256 different wavebands. Those data will be essential to define optimum spectral bands to be collected during the EOS operational phase. Spectroradiometric data will be also collected at different spatial resolution so as to evaluate the impact of ground sample on the relationship between water properties and water reflectance (51).

b2- Water Quality Data Collection

Water parameters to be collected are those necessary to derive the trophic index as defined in the Trophic Index Development Activity. Data will be collected simultaneously with the radiometric data. They will consist of both water samples to be analysed under laboratory conditions and in situ measurements of some water optical properties (penetration depth, for instance).

b3- Algorithm Development

Multispectral and multiviewing water reflectance data obtained simultaneously with measuremets of water quality parameters will be developed. Proposed retrieval variables existing in the literature ((14),(15),(17),(18),(19),(20),(21),(32),(33), and (37)) will be also tested. As reflectance mesurements will be available for 256 different wavelengths, statistical methods for reducing data dimensionality will be applied to them. The expected results of the algorithm development activity is to identify diagnostic spectral regions in terms of their potential to estimate water trophic state. This knowledge is essential to the HIRIS data definition.

c - Selection of Specific Sites for EOS data Acquisition

All the activities previously described will be performed at Tucurui reservoir test site. This proposal however, deals with anthropogenic impacts on Amazonian reservoirs as a whole. So a series of test sites will be selected by the end of the algoritnm development activity. Those test sites will be selected taking into account specific questions which can be raised during that activity. For each of those test sites spectroradiometric data and water quality data will be collected in order to assess the algorithm performance in the pre-EOS data acquisition phase. Those test sites will be defined as prior areas for EOS acquisition.

Operational Phase

During the operational phase EOS data will be received, processed and analysed according to the following phases: a) trophic state index validation and expansion; b) eutrophication modelling and, c) anthropogenic impact assessment of the eutrophication process.

a- Trophic State Validation and Expansion

During this stage HIRIS and MODIS data will be collected over selected sites of the Amazon region. Previously developed algorithms will help to select the spectral configuration and adequate viewing geometry of the HIRIS instrument. This stage will be also supported by ground spectroradiometric measurements and water quality sampling simultaneously with remote sensing data collection. This activity will be performed twice in the the first year of EOS data colection: during a season of minimal variability in trophic index and during a season of maximum variability. This procedure will allow the assessment of the algorithm sensitivity to changes in trophic state under limiting conditions such as very high and/ or very low turbidity. Data collection during different seasonal periods will allow the evaluation of standardising processes for multiple imagery acquisitions (44).

Validation procedures will consist of feeding trophic state algorithms with HIRIS derived reflectance. Trophic index estimations from HIRIS will be statistically compared to in situ measurements for accuracy assessment. Expansion procedures will consist of digitally resampling HIRIS data to the MODIS spatial resolution so as to derive trophic index information over a 500m by 500m ground area. Ground measurements of trophic state will be also averaged over 500m by 500m. Both HIRIS and ground averaged trophic state index will be statisically compared to the trophic state index derived from MODIS data. This procedure will be applied for data collected during both seasonal periods. At the end of this activity the following results are expected: i) A HIRIS algorithm to estimate reservoir's trophic state; ii) a MODIS algorithm to estimate reservoir's trophic state averaged over large areas; iii) accuracy assesment at extreme trophic state conditions and, iv) standardising procedures developed.

b- Eutrophication Modelling

This activity will be accomplished during the second year of EOS data acquisition. It will be based on multistage sampling of MODIS and HIRIS data at one test site. Multistage data will be collected once a month and will allow to model trophic state variation along the year for the selected test site. Auxiliary data will also be collected including: rainfall; catchment basin rivers' discharge; surface runnoff in the catchment basin; conservation practices; deforestation/burning practices; agricultural practices. Monthly trends in trophic index will be correlated to changes in biotic and anthropogenic variables within reservoir's catchment basin. At the same time average trophic state variations will be assessed for the remaining reservoirs at a mesoscale basis provided by MODIS data. The results from this phase will be: a)how abiotic variables such as precipitation, discharge, etc affect water trophic state along the year; b) how anthropogenic variables interact with biotic variables to affect trophic level variability over the time; c) how meso scale changes relate to local scale changes in trophic state addressing questions such as time lags between variation in controlling variables (precipitation, land use) and water trophic level; d) definition of a timetable for EOS data acquisition in the folowing years in terms of the temporal status of the trophic index along the year and, e) identification of the main input variables to derive an eutrophication model from remotely sensed data ((48),(49), and (50)).

c-Determination of Long-term Changes in Eutrophication Process

This activity will be based upon: i) local collection of HIRIS data over selected test sites at least twice a year, during a minimum of 10 years; ii) mesoscale collection of MODIS data at least four times a year, being twice simultaneously with HIRIS and twice in between HIRIS acquisition so as to intercalibrate them and derive intermediate trends along the year; iii) ground data and auxiliary data as previously defined and, iv) data collected during the pre-lauching phase.

Those data will be processed every year to derive the trophic state status of amazon reservoirs. Partial trends in trophic state level will be also determined by integrating over the time all the derived information up to that specific date. The Eutrophication Model will give a partial insight on the environmental variables contributing to trophic state changes along the time. Based on partial trends derived every year, projections will be performed applying temporal modelling techniques, and checked against actual trends computed from EOS data. This comparison will highlight modelling drawbacks and/or changes in the controlling variables over the time (49).

5.0) DATA PLAN

This interdisciplinary investigation on the long term monitoring of the Amazon region will produce an archivable data set. The proposers are ready to commit themselves to the timely provision of this data set to EosDIS in compatible format.

The following data will be necessary for this study:

a)- Data for development of computational experience
Previously acquired data from AVIRIS are requested for developing computational experience with imaging spectroscopy. This previous experience will be helpful for algorithm developments which will be required during EOS operational phase. These data will consist of 1 scene (all bands) from any site and acquisition date, without geometric correction and the same scene with geometric correction;

b)- Data from EOS instruments

b1)-HIRIS

- Nadir pointing level 1-B: 24 scenes in selected bands per year, during 4 years. Before processing any acquisition, a preliminary look product will be examined. These data will be used in the modelling of the land phase of the hydrological cycle;

- Nadir and lateral pointing level 3-B (having as input level 1-B data with 12 bits) with band selection editing mode (visible and near infrared):

- 14 scenes in the first year (1 nadir and 6 lateral pointings obtained in two acquisition dates). They will be used for the development of the Trophic Index algorithm,

- 48 scenes in the second year (1 nadir and 3 lateral pointings, from 12 overpasses, being one per month at different viewing angles). They will be used in the assessment of monthly trends in the water trophic level,

- 6 scenes per year from the 3rd year up to the end of the program (1 nadir and 2 lateral pointings, from 2 overpasses per year). They will be applied to the modelling of the long term relationship between deforestation and water quality;

In summary, it is requested a total of 38 scenes in selected bands of HIRIS for the first year, 72 for the second, 30 for the third and fourth, respectively;

b2) MODIS-N

- levels 1B and 2 products, one scene every six days between December and March and one scene per month during the remaining time: total of 28 scenes, in selected bands, per year (acquisition from the 1st up to the 4th year). They will be applied to the short term modelling of the land phase of the hydrological cycle;

- levels 1A and 1B product, 4 scenes acquired at two different seasons per year: total of 8 scenes in 7 bands obtained for the 1st and the 2nd year and the same scenes at level 2 for the remaining years. They will be used for vegetation mapping and estimation of deforestation rates;

- level 3 products: 30 scenes, in selected bands, one scene every other day during 2 months in different seasons in the first year. They will be used in the expansion of the Trophic Index algorithm;

- level 3 products: 12 scenes , in selected bands (one scene a month) in the second year. They will be used to model the mesoscale changes in water trophic level;

- level 3 products: 4 scenes, in selected bands, per year, from the 3rd year up to the end of the program. They will be used to model the impact of deforestation rates on long term mesoscale water quality changes;

In summary, a total of 66 scenes of selected bands of MODIS-N are recquired for the first year, 48 for the second, and 40 for the third and fourth, respectively;

b3) MODIS-T

- level 3 products : 4 scenes at two different acquisition dates, 7 bands, per year (from the 1st up to the 4th year). These data are requested for the assessment of bidirectional reflectance factor variation of the vegetation cover;

b4) SAR

- level 1.5 products (30m resolution, 4 polarizations, 3 frequencies): 48 scenes per year, (one scene every 3 days between December and March and one per month for the remaining period), from the 1st up to the 4th year. They will be applied to model the land phase of the hydrological cycle as especified in the scientific approach; in addition, eventually, level 1.7 products (radargrammetry, polarimetry, radar cross section, etc.) are requested for special studies (calibration, DEM, soil moisture correlation, etc.);

- level 1.6 and 1.7 products: 6 scenes (two acquisition dates in three swaths), in the global mapping mode for the first through the fourth year (L, C, and X bands in all possible polarizations). They will be applied to evaluate the relationship between deforestation rates and hydrological cycle parameters.

In summary, 55 scenes (including several configurations) are requested for the first through the fourth year;

b5)- ESTAR

-products: 48 scenes per year (one scene every three days between December and March and one scene per month in the remaining months) from the first up to fourth year. They will be used for precipitation and soil moisture estimations.

c) - The following algorithms will be used to provide data products:

c.1) HIRIS and AVIRIS: INPE will test and modify SPAM software algorithms for imaging spectrometry, including the development of digital image restoration algorithms for increased spatial resolution and the development of algorithms for relief effect correction;

c.2) MODIS-N, MODIS-T: development of feature selection and statistical classification (supervised and non-supervised) algorithms.

c.3) SAR: development of speckle noise reduction and segmentation by texture and classification of radar imagery algorithms.

Observations:

INPE has developed experience during the last 13 years in restoration, relief correction, feature selection, and statistical classification. We intend to use SPAM software to acquire experience in imaging spectrometry algorithms. Radar data processing is being initiated.

INPE has also developed microcomputer based image processing systems; accelerating boards for PC-based systems are being developed; in the future larger computers will be available.

The algorithms will be tested by using ground truth data over test areas. The ground truth data will be collected with the support of collaborating Brazilian agencies of the Amazonia, as indicated in the Management Plan. In addition, standard software engineering procedures will be used.

Output products will be provided in magnetic tapes, according to specified formats (IIWG and CCSDS). The data volume corresponds to the required number of scenes as indicated in item 5.b.

Output data will be produced by INPE. Distribution form will be discussed with NASA at a later occasion. It is anticipated that the main user of data will be INPE.

At the present time, due to non-availability of international computer networks in Brazil, mail will be used for reception and distribution of data by magnetic tapes. In the future, the use of computer networks is envisaged.

At the present time, no special requirements for data reception, transmission or processing are identified. Depending upon future negotiations, there is a possibility of direct reception of data at the Cuiaba X-band Ground Receiving Station.

The interdisciplinary team and the image processing facilities are concentrated at INPE. Therefore, we have little need for data distribution. If necessary, magnetic tapes will be mailed to outside participants.

6.0) MANAGEMENT PLAN

The project will be carried out according to three distinct phases: a) definition phase; b)pre-launch phase; and c) operational phase.

a) Definition Phase

a.1) Implementation of Institutional Interfaces - to carry out bureaucratic and legal agreements needed to execute the research proposal.

a.2) Ancillary data acquisition:
- Historical remote sensing data - LANDSAT (TM and MSS), SPOT, and NOAA (AVHRR) from INPE; X - band SLAR data from FIBGE;
- Meteorological data from ground network and DCPs from DNAEE, INEMET/INPE, and/or SUDAM;
- Hydrological data from ground network from DNAEE, ELETRONORTE, and DHN and from DCPs.
- Limnological data from ground network from ELETRONORTE, Emilio Goeldi Museum, INPA, and CVRD;
- Cartographic data from DSG, FIBGE, and DHN;
- Technical reports.

a.3) Implementation of a data base - under a GIS concept to organize the data of item a.2.

a.4) Preliminary data analysis
- to simulate and test the existing hydrological and limnological models; to analyse remote sensing data for land use/land cover change detection; to prepare preliminary reports including selected sites description, results from simulation, and model evaluation.

a.5) Scientific approach evaluation
- it will be developed based on preliminary results and it will be reviewed and updated as needed.

a.6) Scientific report
- preparation of scientific papers including demonstration of algorithms, test of hypothesis, and an updating of the proposal for the pre-launch phase.

b) Pre-launch Phase

I) Modelling the land phase of the hydrological cycle

b.1) Micrometeorological data acquisition
- to define a ground sample design to collect the following data: soil moisture, evapotranspiration, forest interception, etc.

b.2) Conventional hydrological and meteorological data acquisition.

b.3) Remote sensing data acquisition
- to organize and execute annual airborne campaigns to colect data with the following sensors: scatterometer and thermal infra-red radiometer

b.4) Ground data acquisition
- to collect data for the floristic characterization of vegetation communities previously defined with conventional remote sensing means;
- to measure parameters representing forest structure such as: DBH, tree density, leaf size distribution, etc;
-to obtain ecophysiological parameters for dominant tree species: stomatal resistance, leaf area content, etc.

b.5) Data analysis
-to test the hydrological model implemented with ground data
-to compare results from theoretical analysis and simulation with those derived from ground data
-to evaluate and improve model performance

II) Modeling the relationship between deforestation rates and the hydrologic cycle on a yearly basis for a large basin

b.1) Computation of deforestation and hydrological data
-to map annual cumulative deforested area of a selected drainage basin with conventional satellite remote sensing data for a time span of at least twenty years.
- to develop a data base with pluviometric and hydrographic records for the studied basin.

b.2) Implementation of time series of deforestation
-to archive the yearly special distribution of the deforested areas previously mapped in a GIS containing topographic information;
-to determine the time series characteristics of deforestation rates.

b.3) Comparison between deforestation rates and hydrological features
-to analise the relation between the time series of deforestation rate and the time series of the hydrological parameters.

III) Modelling the relationship between nutrients and sediment load and aquatic ecosystems primary productivity

b.1) Trophic index development
-to collect historical and updated water quality data on Tucurui reservoir;

-to analyse the water quality data for spectrally homogeneous water bodies previously defined on conventional remotely sensed data.

b.2) Modelling the relationship between water reflectance and the trophic index
-to organize and execute remote sensing campaigns to collect spectroradiometric data on a helicopter-based instrument simultaneously to water quality data collection;
-to apply feature selection thechniques to the spectroradiometric data;
-to develop algorithms for water trophic level assessment by combining remote sensing and ground based data;

b.3) Selection of test sites for EOS data collection
-to test algorithms performance for different aquatic environments of amazon region;
-to report preliminary results.

c) <u>Operational Phase</u>

I) Modelling the land phase of the hydrologic cycle

c.1) EOS data analysis
-to analyse EOS data for extracting hydrological information;
-to implement hydrological models with remote sensing derived information;
-to compare results from remote sensing models with those derived from conventional models.

c.2) Final model implementation
-to estimate water and energy balance of the selected basin;
-to assess water and energy balance over time;
-to report on the results.

II) Modelling the relationship between deforestation rates and the hydrologic cycle on a yearly basis for a large basin

c.1) Data analysis
-to analyse EOS SAR and MODIS data to extract thematic information.

c.2) Model development
-to model the relationship between deforestation and both water and energy balance over time.

III) Modelling the relationship between nutrient and sediment load and their effects on aquatic ecosystems primary productivity

c.1) Trophic index validation and expansion

-to test trophic index algorithms with HIRIS and MODIS data;

-to evaluate algorithm performance for different environmental frameworks;
-to assess the effect of ground resolution on trophic state.

c.2) Eutrophication modelling
-to derive trophic level information along the year;
-to assess the role of different controlling variables (land use, surface runoff, precipitation, etc., on trophic level variation along the year).

c.3) Determination of long-term changes in the eutrophication process
-to derive trophic level information annually;
-to compute annual changes in trophic level from both remotely sensed data and ground data (calibration only);
-to model time changes in trophic level;
-to correlate trophic level changes with changes in the catchment basin variables;
-to model the trophic level as a function of catchment basin variables derived from remotely sensed data

This proposal will be developed within the scope of the Remote Sensing Basic Research Program of INPE, using the logistic support primarily of the Remote Sensing and Applications Department and the Image Processing Department. Both departments are under INPE's Diretorate and are located at INPE's headquarters in Sao Jose dos Campos, SP, Brazil.

The Center for Hydrological Resources and Applied Ecology/CRHEA, from Sao Paulo University, will be a coinvestigator in the task - relationship between nutrients and sediment load effect on primary productivity of aquatic ecosystems: the eutrophication process. Major interactions are needed for ground data collecting in the aquatic system.

Several collaborating institutions will provide logistic and ground measurement support. Through technical cooperation the commitment letters from these institutions will be sent as soon as possible. Formal commitments are under discussion with the following institutions: INPA (Amazonia Institute of Research); ELETRONORTE (Amazonia Company for Electrical Energy); SUDAM (Amazonia Region Development Authority); CPATU (Center for Cocoa Research); and University of Washigton/School for Oceanography.

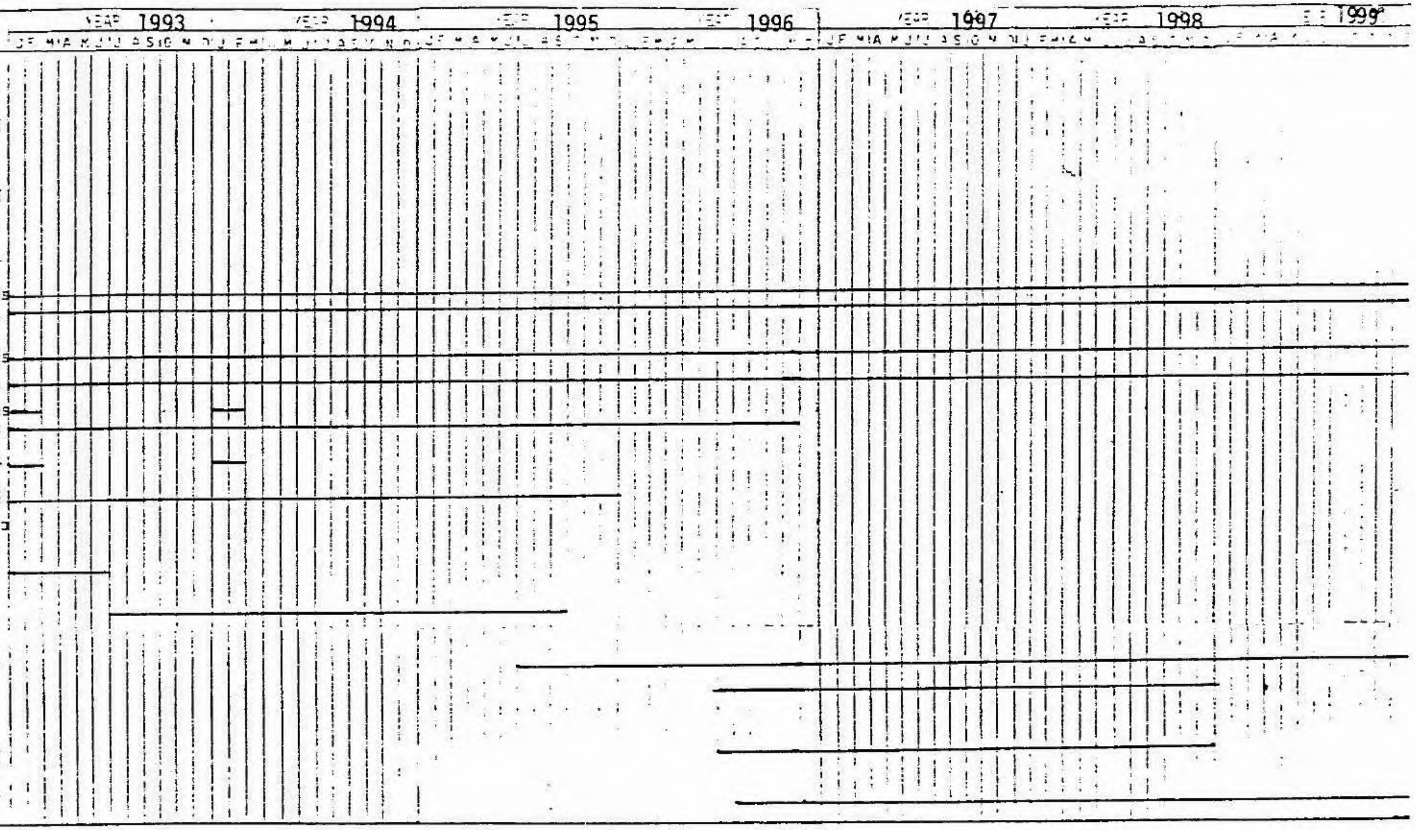
This proposal will be financed by INPE's regular budget through the definition phase. After initial approval, this proposal will be submitted to Brazilian research financing agencies for the pre-launch operational phase support.

TIME-TABLE

TASK	TASK DESCRIPTION	LENGTH OF	TIME		1993	1994	1995	1996	1997	1998	1999
					J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D
a1	Implementation of institutional interfaces	4	months	G.Batista							
a2	Acquisition of Ancillary Data	6	months	Invest.Team							
a3	Implementation of a Data Base	9	months	L.A.Dias							
a4	Preliminary Data Analysis	12	months	Invest.Team							
a5	Scientific Approach Evaluation	4	months	G.Batista							
a6	Scientific Report	6	months	Investigation							
b1	Micrometeorological Data Acquisition Computation of Deforestation Rates			J.V.Soares H.J.H.Kux							
b2	Conventional Hydrological Data Acquisition			J.V.Soares							
	Implementation of time series			H.J.H.Kux							
b3	Remote Sensing Data Acquisition Comparison between D. Rates and Hydrol.			J.V.Soares H.J.H.Kux							
b4	Ground Data Acquisition			D.Valeriano							
b5	Data Analysis			Invest.Team							
c1	Trophic Index Development			E.M.L.Novo							
c2	Modelling the Relationship between TI and water reflectance			E.M.L.Novo							
c3	Selection of Test Sites for EOS data Acquisition			E.M.L.Novo							
d1	EOS data Analysis			Invest.Team							
	Trophic Index validation and Expansion			Invest.Team							
d2	Model Development and Final Model implementation			Invest.Team							
d3	Determination of long term changes in the Eutrophication Process			Invest.Team							

TIME-TABLE (concluded)

TASK	TASK DESCRIPTION	Length of time		Resp.
a1	Implementation of institutional interfaces	4	months	G.Batista
a2	Acquisition of Ancillary Data	6	months	Investigation Team
a3	Implementation of a Data Base	9	months	L.A.Dias
a4	Preliminary Data Analysis	12	months	Investigation Team
a5	Scientific Approach Evaluation	4	months	G.Batista
a6	Scientific Report	8	months	Investigation
b1	Micrometeorological Data Acquisition			J.V.Soares
	Computation of Deforestation Rates			H.J.H.Kux
b2	Conventional Hydrological Data Acquisition			J.V.Soares
	Implementation of time series			H.J.H.Kux
b3	Remote Sensing Data Acquisition			J.V.Soares
	Comparison between D. Rates and Hydrol.			H.J.H.Kux
b4	Ground Data Acquisition			D.Valeria[illegible] inc
b5	Data Analysis			Investigation Team
c1	Trophic Index Development			E.M.L.Novo
c2	Modeling the Relationship between TI and water Reflectance			"
c3	Selection of Test Sites for EOS data Acquisition			"
c¹	EOS data Analysis			Investigation Team
	Trophic Index validation and Expansion			"
c2	Model Development and Final Model Implementation			Investigation Team
c3	Determination of long term changes in the Eutrophication Process			Investigation Team



BIOGRAPHIES OF INVESTIGATORS

Getulio Teixeira Batista

Biography

Getulio Batista received the B.S. degree in agronomy (1970) from the Federal Rural University of Rio de Janeiro, the M.Sc. degree in Remote Sensing (1974) from the INPE. He was a graduate student at the Laboratory for Applications or Remote Sensing (Lars) from 1978 to 1981 and received his Ph.D. degree from Purdue University in 1981 with major in Agronomy and minor in Remote Sensing. He has been working at INPE since 1971. He was the head of the Remote Sensing Department of Inpe for more than five years (from 1982 to 1987) and the Deputy Director of INPE's Remote Sensing Directorate from 1985 to 1987. Currently he is the Coordinator of the Remote Sensing Research Program in Agriculture.

Relevant Scientific and Space-Mission Experience

Over the past seventeen years he has been developing research in the area of crop identenfication, crop conditions assessment, yield prediction modelling, scene characteristics and their relation to classification accuracy, and crop field radiometry. He was a Principal Investigator of a proposal approved under the Early Assessment of SPOT Data Program (PEPS) concerning the comparison of SPOT HRV and TM data for crop identification. He was also a member of the PEPS International Scientific Committee.

In Eos proposal he is the principal investigator and responsible for remote sinsing data for biomass structure studies in deforested areas.

Relevant Bibliography

BATISTA,G.T.,DALLEMAND,J.F., CHEN,S.C., TARDIN,A.T. 1987. Digital and visual analysis of SPOT and TM data for crop discrimination in Southern Brazil. Proc. SPOT-1 Image Utilization, Assessment, Results. Paris, 381-390.

BATISTA, G.T., HIXSON, M.M., BAUER, M.E.1985. Landsat MSS crop classification performance as a function of scene characteristics. Int. Journ. Remote Sens.6 (9):1521-1533.

BATISTA,G.T., RUDORFF,B.F.T. 1988. Study of the spectral response of soybeans. In: XVI Congress of the Int. Soc. Photogram. and Rem. Sensing. (in press).

Joao Vianei Soares

Biography

João Vianei Soares received the BSc and MSc degrees in Agricultural Engineering from the Agriculture School of the Federal University of Viçosa, MG, in 1979 and 1981, respectively. He also held a Doctoral Thesis in "Physical Methods in Remote Sensing" at the University of Paris, France, in 1986. He was an Assistant Teacher on Agrometeorology at the University of São Paulo State (UNESP) from 1981 to 1983. He has been with Brazilian Space Research Institute (INPE) since June 1986, working on microwave systems development and on basic research on microwave remote sensing for Hydrologic purposes.

Relevant Scientific and Space-Mission experience.

Dr. Soares is a co-investigator on a proposal accepted to evaluate ERS-1 data. He is also the principal investigator in a proposal submitted in response to the SIR-C/X-SAR AO. At present he is coordinating a team for a multiparameter scatterometer development.

In Eos proposal he is responsible for microwave data evaluation and hydrologic studies.

Relevant Bibliography.

BERNARD,R.,J.V.SOARES, and D.VIDAL-MADJAR,1886. Differential bare drainage properties from airborne microwave observations. Water Res. Research, Vol 22, No 6, 869-875.

SOARES,J.V., R.BERNARD, and D. VIDAL-MADJAR, 1987. Spatial and temporal behavior of a large agricultural area as observed from airborne C-band scatterometer and thermal infrared radiometer. Int. J. Rem. Sensing, Vol. 8, No 7, 981-996.

SOARES,J.V.,R.BERNARD, O.TACONET, D.VIDAL-MADJAR, and A.WEILL, 1988. Estimation of bare soil evaporation from airborne measurements. Accepted to Journal of Hydrology.

Evlyn M. L. M. Novo

Biography

Evlyn Novo received her B.S. degree in Geography (1973) from University of São Paulo State (UNESP), the M.S. degree in Remote Sensing (1976) from INPE. In 1984 she got her Ph.D. in Physical Geography from Sao Paulo University. Since 1974 she has been a researcher at INPE.

Relevant Scientific and Space-Mission Experience
Dr. Novo obtained her MSc degree with a thesis on Landsat data application to the deforestation assessment in Amazon region. Since then she has been working in various aspects of remote sensing research and applications to environmental analysis, including land use/land cover change detection and water resources monitoring.

In Eos proposal she is responsible for geomorphological and water quality studies.

Relevant Bibliography
NOVO, E.M.L.M. 1983. Effects of solar incidence angle over digital processing of Landsat data. XVII Intern. Symp. on Remote Sens. of Environm.

HERNANDEZ FILHO, P.A.P. SANTOS,; E.M.L.M. NOVO, Y.E.SHIMABUKURO, P. DUARTE, J.S. MEDEIROS,E.C.M. ALVES, C.C. SANTANA, 1980. The use of Landsat for evaluation and characterization of deforested pastureland and deforested areas in Brazil. XIV Int. Symp. on Remote Sens. of Environm.

LOMBARDO,M.A., E.M.L.M.NOVO, M.NIERO, C.FORESTI, 1981. Remote sensing data applied to land use survey at the Paraiba valley. XVII Intern. Sympos. on Machine Processing of Remotely Sensed Data.

Yosio Edemir Shimabukuro

Biography
Yosio Shimabukuro received the BSc degree in Forestry from the Federal Rural University of Rio de Janeiro, Brazil, in 1972. He received the MSc in remote sensing from INPE, in 1977, and Ph.D. in remote sensing from the Colorado State University in 1987. Since 1973, he has been with INPE, where he holds now the position of Coordinator of Remote Sensing Research in Forestry.

In Eos proposal, he is responsible for Vegetation analysis.

Relevant Bibliography
SHIMABUKURO, Y.E., 1987. Shade images derived from linear mixing models of multispectral measurements of forested areas. Ph. D. dissertation, Colorado State University, Fort Collins, Co, U.S.A.

SHIMABUKURO, Y.E., 1983, J.R. SANTOS, L.C.S. AQUINO, 1983. Vegetation survey in Amazonia using Landast data. Proceedings of 7th Internat. Symp. on Rem. Sens. Environ., Ann Arbor, Michigam, U.S.A.

Dalton de Morrison Valeriano.

Biography
Dalton M. valeriano got his BSc degree in Biology-Ecology (1978) at the Federal University of Rio de Janeiro and his MSc degree in Remote Sensing from the Brazilian Space Research Institute (INPE) in 1984. He is employed at this institute since 1982 as a researcher in remote sensing application in vegetation studies.

Relevant scientific and space-mission experience.
Dalton Valeriano's M.S. degree is on classification accuracy assessment of MSS-Landast data applied to environmental monitoring of a region seriously impacted by coal mining activities. Scientific experiences in vegetation studies are on vegetation mapping in the Amazon region with Landsat data, forest studies with aerial photographs, and analysis of spectral signatures of rangelands.

In Eos proposal he is responsible for remote sensing data in vegetation and ecological studies.

Relevant Bibliography
VALERIANO,D.M.; PONZONI,F.J. 1988. CIR aerial photography applied to the evaluation of the air pollution impact in a tropical forest: the case of Cubatao-Brazil.In: XVI Congres. of the Intern. Society for Photogram. and Remote Sens.(in press)

VALERIANO,D.M.; PEREIRA,M.D.B.1988. Relationships between spectral reflectance and phytomass of the ground layer community of neotropical savanna (cerrado). In: XVI Congres. of the Internat. Society for Photogram. and Remote Sens. (in press).

Hermann Johann Henrich Kux.

Biography.
Hermann Kux received his BSc in Geography at São paulo University (USP) in 1970. He got the Doctorate at the Universit Freiburg (Germany) in the field of Geology/ Geomorphology in 1976. From 1977 to 1980 he participated on RADAMBRASIL project in Amazonia, coordinating several mapping sheets. Since 1980 he has been associate reseacher at INPE/ Remote Sensing Department.

Relevant Scientific and Space-Mission Experience
Since 1977 he has worked at mapping of natural resources and on the environment impact of human activities, with remote sensing data.

In Eos proposal he is responsible for microwave data in geomorphological studies.

Relevant Bibliography

KUX,H.J.H.,A.E. BRASIL,and M.S. FRANCO, 1980. Mapeamento geomorfológico da folha SD 20 Guaporé. MME/Projeto RADAMBRASIL, Série Levant. Recursos Naturais, Vol 17.

PINTO, S.A.F., H.J.H. KUX, 1981. Remote sensing data applied to the evaluation of soil erosion caused by land use: a case study in São Paulo State. Proceedings Internat. Symp. on erosion and sediment transport measurement, Florence, Italy.

KUX,H.J.H., L.V. DUTRA, 1984. Evaluation of SIR-A images from the Três Marias region (Minas Gerais State, Brazil) using derived spatial features and registration with MSS-Landsat images. Proceedings XV ISPRS Symp., Rio de Janeiro, Brazil.

Nelson D'Avila Mascarenhas

Biography

Nelson Mascarenhas received the BSc and MSc degrees in Eletronic Engineering from the Technological Institute of Aeronautics, São josé dos Campos, SP, Brazil, in 1966 and 1969, respectively. He also held a Ph.D. in Electrical Engineering from the University of California, obtained in 1974. From 1974 to 1979 was an Associate Professor in the Technological Institute of Aeronautics. Since 1979 he has been a senior researcher at Brazilian Space Research Institute (INPE), São José dos Campos, where he holds now the position of Coordinator of Basic Research Program in Image Processing.

Relevant Scientific and Space-Mission experience.

Dr. Mascarenhas obtained his PhD degree from the University of Southern California in 1974, with a thesis on digital image restoration. Since then he has been working in various aspects of digital image processing and pattern recognition, including edge detection, image classification, texture analysis, image restoration, etc.

In Eos proposal he is responsible for digital image processing studies.

Relevant Bibliography

MASCARENHAS, N.D.A., W.K. PRATTI, 1975. Digital Image Restoration Under a Regression Model. IEEE Trans. Circuits and Systems, Vol CAS-22, no 3, 252-266.

MASCARENHAS,N.D.A, L.O.C. PRADO, 1980. A Bayesian approach to edge detection in images. IEEE Trans. Autom. Control, Vol AC-25, No 1, 36-43 .

MASCARENHAS, N.D.A., L.F.V. FERNANDES, 1980. New methods for picture reconstruction: recursive and causal techniques. IEEE Trans. on pattern analysis and mach. inteligence, Vol PAMI-2, No 4, 369-376.

Luiz Alberto Vieira Dias.

Biography
L.A.V.Dias is an Electronic Engineer, PUC, Rio, Brazil, 1966; M.S. Space Science, INPE, Brazil, 1968; M.S. Rice University, 1971; Ph.D. Rice University, Houston, Texas, Space Physics and Astronomy, 1973. He worked on Space Science until 1980, being INPE's former Coordinator of Basic Research, former Ionospheric Division Head, and former Combustion Division Head. From 1980 on he worked on Computer Science, at the Informatics Department, and Image Processing Department. He spent 7 months in France at the "Universite Paul Sabatier", Toulouse, where he worked on Computer Graphics and Numerical Interpolation. Presently Dr. Dias is working on the same subjects above, and also with computational aspects of remote sensing. He is a senior researcher at INPE, having been former Research and Development Division Head, Informatics Department from 1984 to 1986.

Relevant Scientific and Space-mission Experience
Since 1982 he is involved with computational aspects of remote sensing research, especially on atmospheric correction, relief effect correction, computer graphics, numerical interpolation, and data integration using GIS.

In Eos proposal he is resposible for digital image processing studies.

Bibliography
DIAS, L. A. V.; VIJAYKUMAR, N. L.; CAMARA-NETO, G., 1982 "Procedure for Testing the Quality of LANDSAT Atmospheric Correction Algorithms ".In: REMOTE SENSING AND THE ATMOSPHERE (book). Liverpool, England, Remote Sensing Society , 155-162.

DIAS, L. A. V.; VIJAYKUMAR, N. L.; COSTA-PEREIRA, A. E. 1983. "An Interactive Model for Atmospheric Correction in Satellite Images " In: International Symposium on Remote Sensing of the Environment , 17 Ann Arbor, MI.

DIAS, L. A. V.; DUTRA, L. V.; FELGUEIRAS, C. A.; GODOY JR., M.,1987. " Data integration by Use of Digital Terrain Model and IHS Transformation ". Anal. II Simp. Latinoamericano sobre Sensores Remotos - SELPER, Bogota, Colombia, 91.

Raimundo Almeida Filho.

Biography
Raimundo Almeida Filho received his B.S. degree in Geology (1973) from Brasilia University, the M.S. degree im Remote Sensing (1976) from INPE, and the Ph.D. degree in General Geology and Application (1984) from São Paulo University. From 1974 to 1984 he was an Assistant Researcher at INPE, and since then has been a Associate Researcher. Presently he is in charge of INPE's Remote Sensing Basic Research Program

Relevant Scientific and Space-Mission Experience
His research activities have been focused on the use of computer-enhanced orbital images for geological studies under the Brazilian physiographic conditions. He is particulary interested in scene radiation understanding studies, including relationships between terrain features (rock/soil/vegetation/topography.etc.) and their influence on the signal registrated within each pixel, in different sensor systems, through visible and reflected infrared. Since 1987 he has been the coordinator of the working group to the definition of the general characteristics of the first Brazilian remote sensing satellite.

In Eos proposal he is responsible for remote sensing data in geological studies.

Relevant bibliography
ALMEIDA FILHO,R. 1984. Multiseasonal and geobotanical approach in remote detection of albitized/greisenized areas in the Serra da Pedra Branca granitic massif, Goias state, Brazil.Economic Geology, 79 (8):1914-1920.

ALMEIDA FILHO, R. and I. VITORELLO, 1984. Multiseasonal variables in digital enhancement for geological applications. In: Intern. Congr. on Photogram. and Remote Sensing, XV.Supl, Rio de Janeiro, R.J., Vol. 8, 549-559.

ALMEIDA FILHO,R. 1988. Use of digital images as a mineral prospecting tool in the Tin Province of Goias, Brazil. In: XVI Congress of the International Society for Photogram. and Remote Sensing. (in press).

Luiz Carlos Baldicero Molion

Biography
L.C.B. Molion received his BSc degree in Physics (1969) from São Paulo University, the Ph.D. degree in Meteorology (1975) with minor in Remote Sensing and Hydrology. He spent the year 1982 working at the Institute of Hydrology, Wallingford, UK, as visiting research scientist in the area of Forest Hydrology. He has been working at INPE since 1970, where he was head of the former Department of Meteorology in 1984/1985, director of Atmospheric and Space Science Directorate in 1985/87. Currently, he is the head of Laboratory for Atmospheric and Oceanic Research of INPE.

Relevant Scientific and Space-Mission Experience
Over the past fifteen years, Dr. Molion has devoted his time to study the climate and Hydrology of Amazonia with emphasis on plant-water-atmosphere relationship. He organized with British researchers the Micrometeorological Experiment in Central Amazonia and was the Brazilian Mission Scientist of the two campaigns of the Global Tropospheric Experiment/Amazon Boundary Layer Experiment (GTE/ABLE2), a joint INPE/NASA project. He is currently a member of the working group of land surface Processes and Climate (ISLSCP) and a consultant of IGBP in the area of environment of humid tropical forest.

In Eos proposal he will be responsible for micrometeorological studies and ancillary satellite meteorological data evaluation and application.

Relevant Bibliography

SHUTTLEWORTH et alii,1984. Eddy correlation measurements of energy partition for Amazonian forest. Quart. J. R. Met. Soc. 110, 1143-1162.

MOLION, L.C.B., 1987. On the dynamical climatology of Amazon Basin and associated rain producing mechanisms in Geophysiology of Amazonia. In: DICKINSON, R.E.(Ed.), 391-407 John Willey & Sons.

HARRIS, R.C. et alii, 1988. The Amazon Boundary Layer Experiment (ABLE 24): Dry season 1985. Jour. Geophys. Res., Vol 93(D2), 1351-1360.

Jose Galisio Tundisi

Biography
Dr. Tundisi got his B.S. degree in Natural History (1962) at Sao Paulo University, and his M.S. degree in Oceanography

(1965) from Southhampton University (England), and his Ph.D. degree in Sciences (1974) from Sao Paulo University.

Relevant Scientific Experience
He develops research in comparative limnology of Brazilian rivers and artifitial reservoirs with emphasis on the influence of the physical and chemical parameters on the devolopment of biological communities. He has been a key person for Graduate Students formation in limnologyof reservoirs in Brazil.

In Eos proposal he is responsible for limnololgical studies.

Relevant Bibliography
TUNDISI,J.S.1986. Limnologia de represas artificiais. Bol. Hidräulica e Saneamento, 7:1-46.

TUNDISI,J.G.1984. Estratificação hidräulica em reservatórios e suas consequências ecológicas. Ciência e Cultura, 1489-1496.

APPENDIX 1 - REFERENCES

A-1) MODELING THE LAND PHASE OF THE HYDROLOGICAL CYCLE IN AN UNDISTURBED AREA

1. SALATI,E.,1987. The Forest and the hydrological cycle .In: DICKINSON,R.E.(Ed.). The Geophysiology of Amazonia: Vegetation and Climate Interactions. Wiley,N.Y. Wiley Series in Climate and the Biosphere.

2. SHUTTLEWORTH,W.J., J.H.C. GASH, C.R.LLOYD, C.J. MOORE, J. ROBERTS, A.O.M. FILHO, G.FISH, V.P.S.FILHO, M.N.G.RIBEIRO, L.C.B.MOLION,L.D.ABREU SÁ, J.C.NOBRE, O.M.R.CABRAL, S.R.PATEL and J.C.DE MORAES. 1984. Eddy correlation measurements of energy partition for Amazonian forest. Quart. J. Roy. Meteor. Soc. 110, 1143-1162.

3. DICKINSON,R.E.(Ed.),1987. The Geophysiology of Amazonia: Vegetation and climate interactions. Wiley,N.Y. Wiley Series in Climate and the Biosphere.

4. DICKINSON,R.E.,1987. Introduction to vegetation and climate interactions in the humid tropics. In: DICKINSON,R.E.(Ed.). the Geophysiology of Amazonia: Vegetation and Climate interactions. Wiley,N.Y. Wiley Series in Climate and the Biosphere.

5. DOS SANTOS,J.M.,1987. Climate, natural vegetation, and soils in Amazonia: an overview. In: DICKINSON,R.E.(Ed.). the Geophysiology of Amazonia: vegetation and climate interactions. Wiley,N.Y. Wiley Series in Climate and the Biosphere.

6. FEARNSIDE,P.M.,1987. Causes of deforestation in the Brazilian Amazon.In: DICKINSON,R.E.(Ed.). The Geophysiology of Amazonia: vegetation and climate interactions. Wiley,N.Y. Wiley Series in Climate and the Biosphere.

7. MOLION,L.C.B.,1987. Micrometeorology of an Amazonian rain forest. in: DICKINSON,R.E.(Ed.). the Geophysiology of Amazonia: vegetation and climate interactions. Wiley,N.Y. Wiley Series in Climate and the Biosphere.

8. SELLERS,P.J.,1987. Modeling Effects of vVegetation on climate. In: DICKINSON,R.E.(Ed.). the Geophysiology of Amazonia: vegetation and climate interactions. Wiley,N.Y. Wiley Series in Climate and the Biosphere.

9. FRANKEN,W., P.R. LEOPOLDO, E.MATSUI, AND M.N.G. RIBEIRO,1982. Interceptação das precipitações em floresta amazônica de terra firme, Acta Amazônica, 12,15-22.

10. LEOPOLDO,P.R., W.FRANKEN, E.MATSUI, E.SALATI,1982. Estimativa da evapotranspiração de floresta amazônica de terra firme, Acta Amazônica, 12, 23-28.

11. GEIGER,R.,1975. The climate near the ground. Harvard Univ. Press. Cambridge . 5th ed.

12. RUTTER,J.,1975. The hydrological cycle in vegetation. In: Monteith,J.L.(Ed.). Vegetation and Atmosphere. Academic Press, London.

13. OLDEMAN,R.A.A.,1978. Architecture and energy exchange of dicotyledonus trees in the forest. In: TOMLISON,P.B and ZIMMERNANN,M.H.(Ed.). Tropical trees as living systems. Cambridge,U.K..

14. OLDEMAN,R.A.A.,1983. Tropical rain forest,architecture, silvigenesis and diversity. In: SUTTON,S.L.;WHITMORE,T.C.; CHADWICK,A.C.(Ed.). Tropical Rain Forest: ecology and management. Blackwell Oxford G.B. (special publication number 2 of the British Ecological Society).

15. HARTSHORN,G.S.,1978. Tree falls and tropical forest dynamics. In: TOMLISON,P.B and ZIMMERNANN,M.H.(Ed.). Tropical trees as living systems. Cambridge,U.K..

16. RICHARDS,P.W.,1983. The three-dimensional structure of tropical rain forest. In: SUTTON,S.L.;WHITMORE,T.C.; CHADWICK,A.C.(Ed.). Tropical rain forest: ecology and management. Blackwell Oxford G.B. (special publication number 2 of the British Ecological Society).

17. CARLSON,T.N. 1985. Regional-Scale estimates of surface moisture availability and thermal inertia using remote thermal measurements. Remote Sensing Reviews, 1, 197-247.

18. TACONET,O.,R.BERNARD and D. VIDAL-MADJAR, 1986. Evaporation over an agricultural region using a surface/flux temperature model based on NOOA/AVHRR data. J. Clima. Appl. Meteo., 284-307.

19. TAYLOR,R.S.,R.P. SHUBINSKI and T.S. GEORGE, 1980. Landsat imagery for hydrologic modeling. In: Civil Engeneering Applications of Remote Sensing Speciality Conference, Aerospace Division, American Society of Civil Engeneers, University of Wisconsin, Madison, WI.

20. WIESNET,D.R.,1974. Applications of remote sensing to hydrology. In: World Meteorological Organization Operational Hydrology Report No. 12, Geneve, Switzerland.

21. SOARES, J.V., R. BERNARD, O. TACONET,D. VIDAL-MADJAR and A. WEILL,1978. Estimation of bare soil evaporation from airborne measurements (Accepted for publication on Journal of Hydrology)

22. DIAK, G.R. and C. GAUTIER, 1983. Improvements to a simple physical model for estimating insolation from GOES data, J. Clim. Appl. Meteorol., 22, 505-508.

23. JACKSON, R.D., 1985. Evaluating evapotranspiration at local and regional scales, Proc IEEE, 73, 1086-1096.

24. PRICE, J.C., 1983. Estimation of surface temperature from satellite thermal infrared data. Rem. Sens. Environ. 13, 353-361.

25. SIGH,A. Spectral separability of tropical cover classes. Int. J. of Rem.Sensing, 1987, vol.8, no 7, 971-979.

26. CIMINO,J., A.BRANDINI, D. CASEY, J. RABASSA and S.D. WALL, 1986. Multiple incidence angle SIR-B experiment over Argentina: mapping of forest units. IEEE Trans. Geosc. Rem. Sensing, vol. GE-24 no 4, 498-509.

27. IMHOFF,M., C.VERMILLION, M.H. STORY, A.M. CHOUDHURY, A. GAFOOR and F. POLCYN, 1987. Monsoon flood boundary delineation and damage assesment using spaceborne imaging radar and Landsat data. Photogram. Eng. Remote Sens., vol 53,no.4, 405-413.

28. WILLIAMS, D.L. and R.F. NELSON, 1986. Use of remotely sensed data for assessing forest sStand conditions in the Eastern United States. IEEE Trans. Geosc. and Remote. Sens. Vol GE-24, No 1, 130-138.

29.WESTMAN,W.E and J.F. PARIS, 1987. Detecting forest structure and biomass with C-band multipolarization Radar: Physical model and field tests. Remote Sens. of Environ. 22, 249-269.

30. IMHOFF,M., M. STORY, C. VERMILLION, F. KHAN, and F. POLCYN, 1986. Forest canopy characterization and vegetation penetration assessment with space-borne radar. IEEE Trans. Geosc. and Remote Sens. Vol GE-24, No 4, 535-542.

31. PETERSON, D.L., W.E. WESTMAN, N.J. STEPHENSON, V.G. AMBROSIA, J.A. BRASS, SPANNER,M.A,1986. Analysis of forest structure using Thematic Mapper simulator data. IEEE Trans. Geosc. Rem. Sensing, Vol GE-24, No 1, 113-121.

32. BUTERA, M.K., 1986. A correlation and regression analysis of percent canopy closure versus TMS spectral response for selected forest sites in the San Juan National Forest, Colorado. IEEE Trans. on Geosc. Remote Sens., vol GE-24, No 1, 122-129.

33. DANSON, F.M.,1987. Preliminary evaluation of the relationship between SPOT-1 HRV data and forest stand parameters. Int. J. Remote Sens., 8, No 10, 1571-1575.

34. MORAIN, S.A.,1974. Phenology and remote Sensing. In: LIETH,h.(Ed.) Phenology and Seasonality Modeling. Springer-Verlag, Berlim, (Ecological Studies £ 8).

35. JACKSON,R.D.,1986. Remote sensing of bBiotic and abiotic plant stress. Ann. Rev. Phytopathol., 24, 265-287.

36. TUCKER,C.J., PJ. SELLERS, 1986. Satellite remote sensing of primary production. Int. J. Remote Sens., vol 7, no.11, 1395-1416.

37. SCHMUGGE,J., 1987. Remote sensing applications on hydrology. Reviews of Geophysics, Vol. 25, 148-152. U.S. National Report to the International Union of Geodesy and Geophysics 1983-1986.

38. TACONET,O., T.N. CARLSON, R. BERNARD, and D. VIDAL-MADJAR, 1986. Evaluation of a surface vegetation parameterization using satellite measurements of surface temperature. J. Climat. Appl. Meteor., 25, 1752-1767.

39. LEWIS,E.L.,1983. Compatibility of present hydrologic models with remotely sensed data. In: Proceedings of the Seventeenth International Symposium on Remote of Environment, Ann Arbor, Michigam, pp. 133-153.

40. BARTH,F.T., C.T. POMPEU, H.D. FILL, C.E.M. TUCCI, J.KELMAN and B.P.F. BRAGA JR., 1987. Modelos para gerenciamento de recursos hídricos. São Paulo, Nobel/ABRH. 526 p.

41. ULABY, F.T., J. BARR, A. SOBTI, and R.K. MOORE, 1974. Soil moisture detection by Skylab'smicrowave sensors. In: Proceedings of URSI Commission II Specialist Meeting, p.205, Berne, Switzerland.

42. BLANCHARD,B.J., A.J. BLANCHARD, S. THEIS, W.D. ROSENTHAL, C.L. JONES, 1981. Seasat SAR response for water resources parameters, Final Report 3891, Remote Sensing Center, Texas A & M University, Texas.

43. RODDA,J.C., 1976. Facets of hydrology. John Wiley & Sons, N.Y.

44. BERNARD,R.,P. LANCELIN, and G. LAURENT, 1987. Radar observation of the Guyana rain forest : Campaign Report. Note Technique CRPE/156, Centre de Recherches en Physique de l'Environnement, Paris.

45. ULABY, F.T., D. HELD, M.C. DOBSON, K.C. McDONALD, and T.B.A. SENIOR, 1987. Relating polarization phase difference of SAR signals to scene properties. IEEE Trans.Geosc. Remote Sens., vol. GE-25,no.82.

46. SCOFIELD,R.A, and V.G. OLIVER, 1979. A satellite derived technique for estimating rainfall from thunderstorms and hurricanes. In: Proceedings of the 5th Annual W.T. Pecora Memorial Symposium on Rem. Sensing, Satellite Hydrology. American Water Resources Association, Sioux Falls, SD.

47. ASSAD, E.D., 1987. Utilisation des satellites meteorologiques pour le suivi agroclimatique des cultures en zone sahelienne: Cas du Senegal. Université des Sciences et Techniques du Languedoc. Doctoral Thesis.

48. DEARDORFF,J.W., 1978. Efficient prediction of ground surface temperature and moisture, with inclusion of a layer of vegetation. J.G.R. vol.83,no.4, 1889-1903.

49. SOARES,J.V., and H.J.H. KUX, 1987. Microwave remote sensing data from a spaceborne platform as a tool to monitore the hydrological cycle of a floodplain area ("Vãrzea") at northeast Brazil, (test site: Petrolina, Pernambuco State, Brazil). Proposal submitted to NASA/DFVLR in response of the SIR-C/X-SAR AO.

50. SOARES,J.V.,1986. Characteristiques spatialles et temporelles d'une region agricole observée a l'aide d'un diffusiometre en hyperfréquences et d'un radiometre dans l'infrarouge thermique aeroportés. Université de Paris 7. Doctoral Thesis.

51. SAXTON, K.E., H.P. JOHNSON, and R.H. SHAW, 1974. Modeling evapotranspiration and soil moisture. Transactions of the ASAE,17, 673-677.

52. LANG,A.R.G.; X. YUEQUIN, 1986. Estimation of leaf area index from transmission of direct sunlight in discontinuous canopies. Agricultural and Forest Meteorology. Vol 37 no.3, 229-243.

53. MARSHALL,J.D., R.H. WARMING, 1986. Comparision of methods of estimating leaf area index in Old-Growth Douglas Fir. Ecology, Vol 67, no.4, 875-879.

54. BONHOMME, R., 1973. Analyse de la surface des taches de soleil, de l'indice foliaire et de l'inclinaison moyenne des feuilles à l'aide des photographies hemispheriques. In: SLAYTER ,R.D. (Ed.). Plant response to climatic factors. UNESCO, Paris, 369-376.

A-2) MODELLING THE RELATIONSHIP BETWEEN DEFORESTATION RATES AND THE HYDROLOGIC CYCLE ON A YEARLY BASIS FOR A LARGE AMAZON BASIN.

1. FEARNSIDE,P.M.,1985. Brazil's Amazon forest and the global carbon problem. Interciencia, Vol 10 No 4, 179-186. amazon forest and the golbal carbon problem. Interciencia, Vol 10, No 4, 179-186.

2. MALINGREAU,J.P, and C.J. TUCKER, 1987. The contribution of AVHRR data for measuring and understanding global processes: large scale deforestation in the Amazon basin. Proceedings IGARSS'87 Symposium, Ann Arbor , 443-448.

3. NELSON,R and B. HOLBEN,1986. Identifying deforestation in Brazil using multi-resolution satellite data. Internat.J. of Remote Sensing, Vol 7 No 3, 429-448.

4. DOMIK,G, 1987. Methods and application of surface shape reconstruction from multiple SAR images. Proceedings IGARSS' 87 Symposium, Ann Arbor,1551-1555.

5. DOMIK,G, F.LEBERL, J.B.CIMINO, 1986. Multiple incidence angle SIR-B Experiment over Argentina: generation of secondary image products. IEEE Trans.Geoscience & Remote Sensing. Vol.GE-24 , No 4,492-497.

A.3) Modelling the relationship between nutrient and sediment load and aquatic ecosystem primary productivity.

1. FISCHER,T.R., 1979. Plancton and primary production in Aquatic systems of Central Amazon Basin. Amazoniana 1: 267-272.

2. FEARNSIDE, P.M. and J.K. RANKIN, 1983. Jari and Carajas: The uncertain future of Large Silviculture Plantation in the Amazon. Interciencia 7960: 326-329.

3. TARDIN,A.T., A.P.SANTOS, E.M.L.M.NOVO, F.L.TOLEDO, 1977. Relatorio de Atividades do Projeto SUDAM/INPE durante o ano 1976/1977, Sao Jose dos Campos, INPE, (INPE-1034-NTE/099).

4.SANTOS, A.P., E.M.L.M NOVO, 1977. Uso de dados LANDSAT-1 na implantacao, controle e acompanhamento de projetos agropecuarios no sudeste da Amazonia Legal, Sao Jose dos Campos, INPE, (INPE- 1044-TPT/056).

5. GOULDIE,A.,1984. The human impact: man's role in environmental change. Cambridge, The MIT Press.

6. HENRY,R., K. HINO, J.C. GENTIL, J.G. TUNDISI, 1985. Primary production and effects of environment with Nitrate and Phosphate on phytoplankton in the Barra Bonita Reservoir. (State of Sao Paulo), Int. Rev. Ges. Hydrobiology 70(4):561-573.

7. TUNDISI,J.G., 1986. Limnologia de Represas Artificiais, Boletim de hidraulica e saneamento 11:1-46.

8. BARBOSA, F.A. and J.G. TUNDISI, 1980. Primary production of phytoplankton and environmental characteristics of a shallow quaternary lake at eastern Brasil. Archives of Hidrobiology 90(2):139-161.

9. WERZENAK,C.T., 1973. The use of remote sensing in limnological studies, Proceedings of the 9th internat. symp. rem. sens. of environ. Ann Arbor: University of Michigan, 965-980.

10. SIOLI,H., 1968. Hydrochemistry and geology in the brazilian amazon region, Amazoniana 1.

11. JUNK,W.J.,1983, As aguas da regiao amazonica In: SALATI,E. et al (Ed.) Amazonia : desenvolvimento , integracao e ecologia. Sao Paulo. Ed. Brasiliense.

12. KIRK,J.T.O.,1986. Light and photosynthesis in aquatic ecosystems, Cambridge, Cambridge University Press.

13. NEVILLE,R.A. and J.F.R. GOWER, 1977. Passive remote sensing of phytoplankton via Chlorophyll-a fluorescence, Jour. geoph. research, 82:3487-3493.

14. KIM,H., C.R. MCCLAIN, and W.D. HART, 1979. Chlorophyll gradient map from high-altitude ocean-colour-scanner data. Appl. optics, 18:3715-4716.

15. GORDON, H.R. and D.K. CLARK, 1980. Atmospheric effects in the remote sensing of phytoplankton pigments. Boundary layer meteo., 18:299-313.

16. MOREL, A., 1980. In-water and remote measurements of ocean colour. Boundary layer meteo., 18:117-121.

17. CARDER,K.L., R.G. STEWARD, J.H. PAUL, G.A. VARGO, 1986. Relationship between chlorophyll and ocean colour constituents as they affect remote sensing reflectance models. Limnol. oceano., 31:403-410.

18. HOLYER, R.J., 1978. Towards universal suspended sediment algorithm. Rem. sens. environ., 7:323-338.

19. MUNDAY, J.C., and T.T. ALFOLDI, 1979. Landsat test of diffuse reflectance models for aquatic suspended solid measurements. Rem. sens. environ., 8:169-183.

20. TASSAN,S.,1981. A method for retrieval of phytoplankton and suspended sediment concentration from remote measurements of water colour. Proceed. 14th intern. symp. rem. sens. environ., Ann Arbor:University of Michigan, 577-586.

21. TASSAN, S., and B. STURM, 1986. An algorithm for the retrieval of sediment content in turbid coastal waters from CZCS data. Int. J. rem. sens., 7(5): 643-655.

22. WHITLOCK, C.H., W.G. WITTE, J.W. USURY, and E.A. GURGUNUS, 1978. Penetration depth at green wavelengths in turbid waters. Photog. engin. rem. sens., 44:1045-1048.

23. WITTE, W.G., C.H. WITLOCK, R.C. HARRIS, J.W. USURY, L.R. POOLE, W.M. HOUGHTON, W.D. MORRIS, E.A. GURGUNUS, 1982. Influence of dissolved organic material on turbid water optical properties and remote sensing reflectance. J. geoph. research 87(1):441-446.

24. LINK, L.E.,K.S. LONG, 1978. Large scale demonstration of aquatic plant mapping by remote sensing. Proceed. 20th int. symp. rem. sens. environ., Ann Arbor:University of Michigan.

25. BUKATA,R.P., J.E. BRUTON, J.H. JEROME, 1982. The futility of using remotely determined chlorophyll concentration to infer acid stress in lakes. Can. J. rem. sens., 8:38-42.

26. GOLTERMAN, H.L., R.S. CLYMO, M.A. OHNSTAD, 1978. Methods for physical and chemical analysis of fresh waters. IBP Handbook 8, Oxford, Blackwell Scientific Publications.

27. TUNDISI, J.G., 1984. Estratificacao Hidraulica em reservatorios e suas consequencias ecologicas. Ciencia e cultura: 1489-1496.

28. CORDEIRO NETO,O.M., S.A.P. COLARES, 1985. Aplicacao de modelos simplificados para a avaliacao do nivel de eutrofizacao dos lagos Paranoa e Descoberto no Distrito Federal. RBE 3(2):21-35.

29. KIRK, J.T.O., 1980. Relationship between nephelometric turbidity and scattering coefficients in certain australian waters. Austral. J. mar. freshwat. res., 31:1-12.

30. SPENCE,D.H.N., 1981. Light quality and plant responses under water. In: SMITH, H.(Ed.) Plants and daylight spectrum. London. Academic Press.

31. PREISENDORFER, R.W., 1976. Hydrologic Optics. Honolulu Joint Tsunami Experiment.

32. PRIEUR, L., and S. SATHYENDRANATH, 1981. An optical classification of coastal and oceanic waters based on the specific absorption curves of phytoplankton pigments, dissolved organic matter and other particulate material. Limnol. oceano., 26:671-685.

33. PERRY, M.J., 1986. Assessing marine primary productivity from space. Biosc., 36(71):461-467.

34. MOREL,A., and L. PRIEUR, 1977. Analysis of variations in ocean colour. Limnol. oceano., 22:709-711.

35. GORDON, H.R., D.K. CLARCK, J.W. BROWN, O.B. BROWN, R.H. EVANS, W.W. BROENKOW, 1983. Phytoplankton pigment concentration in the middle atlantic bight: comparison of ship determinations and CZCS estimates. Appl. optics, 22:20-37.

36. GOWER, J.F.R., 1984. Water colour imaging from space. In: NIHOUL,J.C.J. (Ed.) Remote sensing of Shelf Sea Hidrodynamics: 1-24. Amsterdan, Elsevier.

37. BENTLEY, J.G.,1987. Estimating suspended sediment concentration from remotely sensed data in the visible spectrum. Sheffield: Department of Geography. University of Sheffield Report.

38. INPA/ELETRONORTE, 1982. Relatorio Semestral - Estudos limnologicos no sistema Tocantins / Araguaia - Qualidade da Agua. Manaus, INPA.

39. SYDOR, M., 1980. Remote sensing of particulate concentrations in water. Appl. optics, 19(16):2794-2800.

40. SIMMER, C., and S.A.W. GERSTL, 1985. Remote sensing of angular characteristics of canopy reflectances. IEEE Trans. geosc. rem. sens., Vol GE-23:648-653.

41. NOVO, E.M.L.M., 1988. The impact of multiviewing reflectance data on the estimation of suspended sediment concentration. IGARSS'88, Edimburgh (in press).

42. NOVO, E.M.L.M., and M. GODOY JUNIOR, 1988. Multiviewing linear models for estimating suspended sediment concentration (SSC) from remotely sensed data. ISPRS,1988, Kyoto (in press).

43. NOVO, E.M.M., J.D. HANSOM, and P.J. CURRAN, 1988. The effect of viewing geometry on the relationship between reflectance and suspended sediment concentration. Int. J. rem. sens (in press).

44. ROLLIN, E.M., and M.D. STEVEN, 1986. Standardising multiple imagery using irradiance data. In: BRADBURY AND ROLLIN (Ed.) Ground Truth for Remote Sensing. 213-219. Nottinghan. Remote Sensing Society.

45. SCHMIDT, G.W., 1976. Primary production of phytoplankton in the three type of amazonian waters. Amazoniana 4:517-528.

46. COIMBRA, C.A., 1984. Ecossistemas Aquaticos: Exame de uma Cinetica. Rio de Janeiro (LCC-024/84).

47. LONDRES,H., 1985. Sinopse sobre as caracteristicas das aguas amazonicas. Rio de Janeiro (LCC-030/85).

48. KRITZ, M.V., 1985. Analise limite e Lagos Artificiais. Rio de Janeiro. (LCC-016/85).

49. KRITZ, M.V., 1985. Modelagem de Ecossistemas. Rio de Janeiro. (LCC-013/85).

50. KRITZ, M.V., 1985. Problemas Matematicos na modelagem de sistemas amazonicos. Rio de Janeiro. (LCC-007/85).

APPENDIX 2 - TABLES AND ILLUSTRATIONS.

Table 1 - Ecological Parameters of Brazilian Reservoirs (*)

Reservoir	Volume m x 10	Drainage basin	Phytoplankton primary prod. mg/m /day	Clorophyll mg/m	Secchi depht (m)
Capivara	10800	Paranap.	188.6	11.74	1.90
B. Bonita	200	Tiete	388.2	15.91	1.20
Promissao	6140	Tiete	584.0	68.68	3.00
I. Solt.	27375	Parana	248.3	20.21	3.65

(*) data from (27). They represent an average of four measurements taken along the year at very seasonal period.

Table 2 - Environmental Data Recorded at Lake C for the Winter (July, 1977) and Summer (January, 1978) (*)

Environmental variables	Winter	Summer
pH	5.8	7.2
conductivity	26.5	21.9
alkalinity (meq/l)	0.150	0.243
CO2 total (mg/l)	28.97	12.10
total inorg. C (mg/l)	7.90	3.30
susp. mat. (mg/l)	4.8	5.1

(*) data collected at zero depth in one station from (8)

APPENDIX 2 - TABLES AND ILLUSTRATIONS (Cont.)

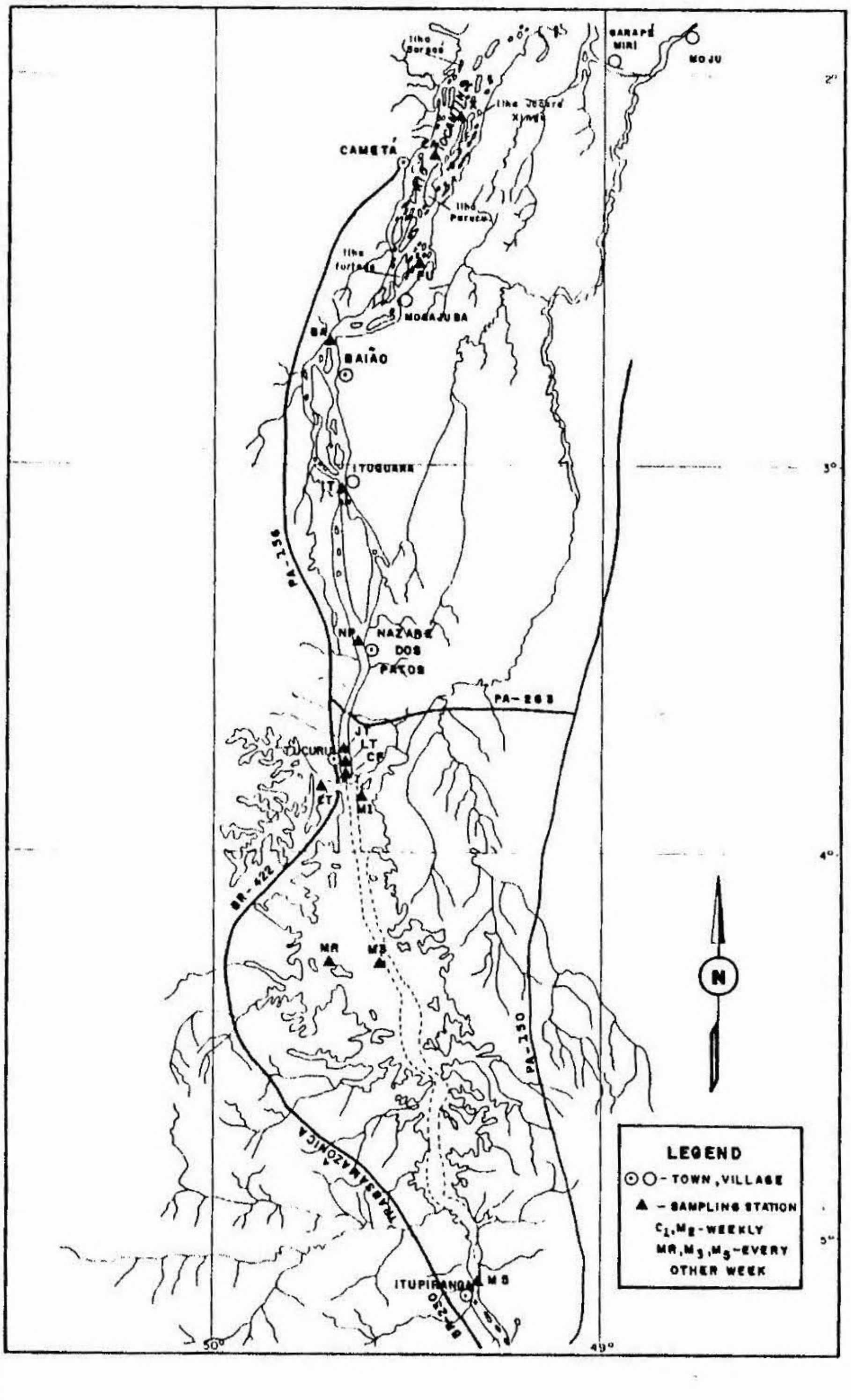
Table 3 - Improvements on Remotely Sensed Data (*)

improvement	technical requirement
aerosol correction	add infrared bands
improve pigment characterization	add visible bands
mapping smaller changes in sediment/pigment concentration	increase sensitivity
distinguish between yellow substance & phytoplankton	add band near 400 nm

(*) from (36).

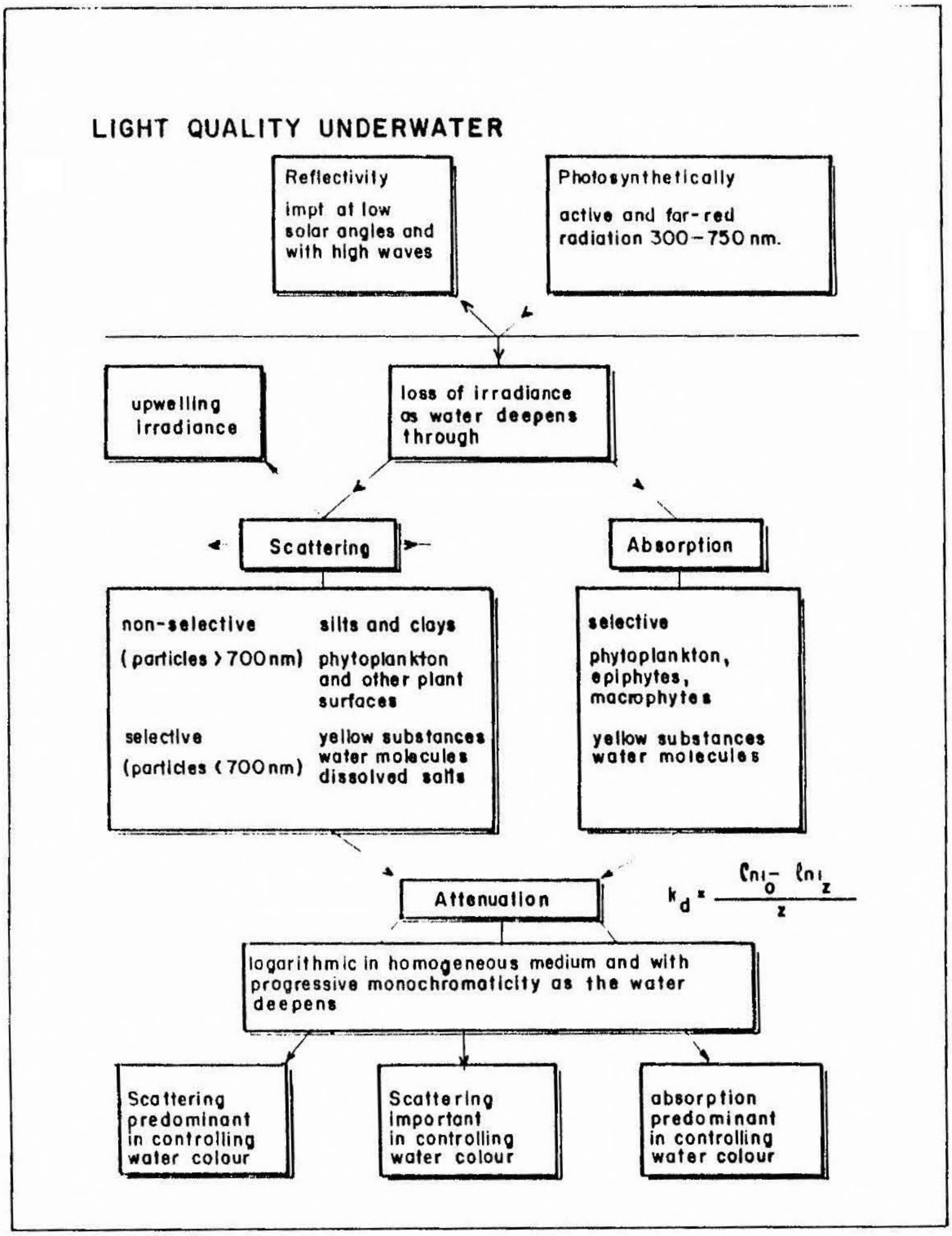
APPENDIX 2 - TABLES AND ILLUSTRATIONS (Cont.)

Figure 1 - Sampling Design at the Tucurui Reservoir



APPENDIX 2 - TABLES AND ILLUSTRATIONS (Cont.)

Figure 2 - Characteristics of the underwater light field. (Source (30)).



APPENDIX C - COMMITMENT LETTERS

MINISTÉRIO DA CIÊNCIA E TECNOLOGIA
INSTITUTO DE PESQUISAS ESPACIAIS

São José dos Campos, June 13, 1988.

DG-0394/88

Dr. Dixon Buttler
Program Scientist
Earth Observing System
Code EPM-20 (Ref. AO No. OSSA -1-88)
NASA Headquarters
Washington, DC 20546
USA

Dear Dr. Buttler:

The purpose of this letter is to certify that the Brazilian Institute for Space Research (INPE) will support the enclosed proposal submitted in response to the Eos AO No. OSSA-1-88 and will sponsor it through the Definition Phase. INPE also agrees with the Management Plan proposed by its scientists.

This proposal is an initiative of Brazilian scientists with great experience in remote sensing, large scale climatic changes, and water quality studies who envisage Eos as a powerful means to understand complex ecosystems in a scientific basis.

It is also our belief that Eos represents a very important advancement to the remote sensing technology permitting a better understand of the Planet Earth as a whole.

We look forward to participating in this most distinguished NASA program.

Yours sincerely,

Dr. Marco Antonio Raupp
Director General

UNIVERSIDADE DE SÃO PAULO

CENTRO DE RECURSOS HÍDRICOS E ECOLOGIA APLICADA

RHEA

S. Carlos, June 10, 1988

Exmo. Sr.

Dr. GETÚLIO TEIXEIRA BATISTA

Instituto de Pesquisas Espaciais

SÃO JOSÉ DOS CAMPOS - SP

Dear Dr. Batista:

It was a honour to receive and accept the invitation to participate in the Project long term monitoring of the Amazon Ecosystems throughout the EOS, to be submited to the NASA Earth Observing System Program.

As you know I have particular interest in limnological studies in the Amazon Basin, and have been working in the region for the last few years. I have particular interest in the new Amazonian reservoirs.

Yours Sincerely,

Prof. J. G. Tundisi

Diretor do CRHEA

De acordo

Luiz Di Bernardo

Chefe Suplente em exercício

Depto.Hidr. e Saneamento

Avenida Dr. Carlos Botelho, 1465 - CEP 13.560 - Fone: 4246 - SÃO CARLOS - S.P.

UNIVERSIDADE DE SÃO PAULO
CAMPUS DE PIRACICABA
ESCOLA SUPERIOR DE AGRICULTURA "LUIZ DE QUEIROZ"

June 3, 1988

Dr. Getulio Teixeira Batista
Remote Sensing
Instituto Nacional de Pesquisas Espaciais
São José dos Campos-SP

Dear Dr. Batista,

It was an honor to receive and accept the invitation to participate as a collaborator in the project "Long Term Monitoring of the Amazon Ecosystem Traigh the EOS: from Patterns to Process", to be submited to the NASA Earth Observing System Program. As you know I have particular interest in hidrological and biogeochemical cycles in the Amazon Basin, and have been working in the region for the last few years. We built a considerable data base that could be of great help for the project. As you also know, my collaboration in the project does not imply any salary payment, that will continued to be paid by USP.

Thanking you again for the invitation I remain

Sincerely yours

Dr. Reynaldo Luiz Victoria
Assiciate Professor Dept. of Physics and
Meteorology ESALQ/USP

in accordance:

Dr. Humberto de Campos
Director/ESALQ/USP

Dr. Nilson Augusto Villa Nova
Head, Dept. of Physics and Meteorology

UNIVERSIDADE DE SÃO PAULO
CAMPUS DE PIRACICABA

cena

USP

Centro de Energia Nuclear na Agricultura

June 3, 1988

Dr. Getulio Teixeira Batista
Remote Sensing
Instituto Nacional de Pesquisas Espaciais
São José dos Campos-SP

Dear Dr. Batista,

It was an honor to receive and accept the invitation to participate as a collaborator in the project "Long Term Monitoring of the Amazon Ecosystem Traigh the EOS: from Patterns to Process", to be submited to the NASA Earth Observing System Program. As you know I have particular interest in hidrological and biogeochemical cycles in the Amazon Basin, and have been working in the region for the last few years. We built a considerable data base that could be of great help for the project. As you also know, my collaboration in the project does not imply any salary payment, that will continued to be paid by USP.

Thanking you again for the invitation I remain

Sincerely yours

Luiz Antonio Martinelli

in accordance:

Dr. Frederico M. Wiendl
Director CENA/USP

13.400 - PIRACICABA - SP - BRASIL - CAIXA POSTAL 96 - FONE (0194) 33.5122 - TELEX (019) 1097 - END. TELEG. "CENA"