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Space Technology for E-health

Space technology-based tele-health project initiatives in Latin America and the Caribbean

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United Nations Programme on Space Applications

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PREFACE

The United Nations Programme on Space Applications (the Programme) was created in 1971. The Programme is aimed at promoting, through international cooperation, the use of space technologies and data for sustainable economic and social development in developing countries. The priority areas of the Programme are: disaster management, satellite communications for tele-education and tele-health applications including the prevention of infectious diseases, monitoring and protection of the environment, management of natural resources, and education and capacity-building in areas including research in basic space sciences. In each priority area, the Programme aims to promote capacity-building in space technology and awareness-raising among decision makers that strengthens local support for the operational use of space technologies.

In the area of tele-health, the Programme has been conducting workshops and training courses in different regions since 2005. For the Latin America and Caribbean Region, the Programme conducted a Workshop on the Use of Space Technology for Human Health in September 2005 in Argentina. The Workshop was co-organized with the National Commission of Space Activities of Argentina (CONAE) and was held at the Gulich Institute of Advanced Space Studies, Tabanera Space Center in Córdoba, Argentina. The objectives of the Workshop were to demonstrate the use of space technology for health (in particular landscape epidemiology) and to share information on health-related activities and applications for Latin America and the Caribbean Region with a view toward launching regional projects on landscape epidemiology.

The participants of the Workshop represented 21 countries and they initiated a task force in the region called the "Pan-american Tele-Epidemiology Group" (PTEG). This alliance focuses on utilization, development and exchange of space technologies applied to public health, and provides the necessary "critical mass" of participants throughout the Latin American and Caribbean region.

The task force PTEG took its first action by presenting a series of new and ongoing Latin American Tele-Health and Tele-Epidemiology projects to the ISfTeH 2006 Med-e-Tel 2006 Conference held in April in Luxembourg. These presentations were delivered in a dedicated poster session and an oral presentation session that were co-organized by the UN Programme on Space Applications, the PTEG, and Med-e-Tel Conference. New and on-going Tele-health projects were subsequently presented in a dedicated session during the XII Symposium of the Latin American Society in Remote Sensing and Spatial Information Systems (SELPER) held in Cartagena, Colombia on September 2006.

This book contains selected papers and posters that were presented in the Med-e-Tel Conference and the SELPER in 2006. The PTEG continues to progress successfully. In 2006, the Group, facilitated by the Programme, iinitiated cooperation agreements among Argentina, Bolivia, Chile, Ecuador, Italy, Paraguay, and Peru. In addition, Group members from Venezuela, Peru, Colombia, and Ecuador initiated a regional project on preventing Malaria using space technology.

We thank all the dedicated authors who contributed to the work and this publication. The authors have expertise in either space technologies, medical care services or both. Tele-health is an integrated application that requires a combination of space technologies and medical services. We respect all the authors for their dedicated efforts to advance the medical services using space technologies. Since this book is a collection of the current projects in Latin America and the Caribbean Region, most of the authors of this book are Latin Americans and with Spanish as their mother tongue. We appreciate that they have made special efforts to write in English for our English readers. We present their original writing without any editing in this book in order to keep the original flavour.

Special thanks are extended to Dr. Professor Maria del Mar Lleo of Italy for her tremendous contribution in coaching and coordinating with all the authors for the applications, collecting inputs, editing and compiling them into this book.

Special thanks also are extended to Dr. Marcello Scavuzzo of Argentina for his tireless promotion of tele-epidemiology for the region, and coordination effort for the task force PTEG.

The Argentina National Space Activities Commission and the Gulich Institute are the main driving forces for the work planned for the Group. In May 2007, they begin to offer an annual 6-week training course under the United Nations/Argentina Fellowship Programme on Advanced School for Training in Landscape Epidemiology at the Institute for Advanced Space Studies Maria Gulich, Argentina. This Fellowship will contribute greatly in providing necessary critical mass in tele-epidemiology applications for the Latin American and Caribbean Region.

It is our hope that this book will contribute to a general recognition of the important role that space technologies can play in the tele-health, and of space technologies' essential contribution to expand the traditional means of providing medical care to remote communities.

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Introduction

eHealth is the process of using information and communication technologies to deliver health information, services, and expertise over long and short distances. eHealth applications are important tools for enhancing health care delivery, particularly in impoverished, rural and remote areas where health care resources and expertise are often scarce or non-existent. These applications can be grouped into four main areas:

- eCare and Teleconsultation (telemedicine, teleimaging, healthcare at home),
- eLearning (education/training in health disciplines, telelearning, telementoring),
- eSurveillance (public health and disease reporting, real-time epidemiology, management of health consequences of natural and man-made disasters), and
- eAdministration.

These disciplines are now emerging under continuous development. Two specific areas derive well-identified benefits from the use of space technologies. These are Tele-medicine and Tele-epidemiology (or Landscape Epidemiology). Telemedicine can provide quality diagnosis and medical advice for extremely isolated areas and populations; Tele-epidemiology helps in predicting and combating infectious diseases.

Residents of remote areas in developing countries often have very limited or no access to medical services because of inadequate road conditions and the lack of transportation infrastructure. A Telemedicine program for such areas can extend health service coverage and can improve its quality. The program can enable integral health care, including prevention, diagnosis, treatment, rehabilitation activities and public health education. Space technologies such as satellite communications and Remote Sensing can be used to deliver health services to remote communities.

The SARS epidemic and the present risk of an avian flu pandemic highlight the important epidemic risks of emerging or re-emerging diseases. Moreover, a close relationship between the environment and several infectious diseases (such as vector-borne, rodent-borne and water borne diseases) has been also recognised. One can infer that an increase of these diseases in the near future is likely because of human population growth, increasing mobility, the spread of virus serotypes and vectors/hosts, and effects related to climate change or global warming. Such unpredictable health threats can be significantly mitigated by prevention as well as by early warning and prompt management when a threatening disease outbreak occurs. Detection and monitoring of potential risks become an important part of so-called “Epidemic Intelligence”. Satellite communication and environmental monitoring using space technologies can enable health early warning systems in remote areas or in areas prone to natural or man-made disasters. Tele-Epidemiology can be used to predict the possibility of a potential epidemic outbreak and significantly reduce the risk of disease onsets.

In this context, the “Workshop on the Use of Space Technology for Human Health” was held for the benefit of Latin American and Caribbean Countries. It was held from 19 to 23 September 2005 in the Teofilo Tabanera Space Centre of the National Commission of Space Activities of Argentina (CONAE) in Cordoba, Argentina. The event was attended by participants from 21 countries and was organised under the sponsorship and with the participation of UN/OOSA, ESA, PAHO and several European and USA Universities. The prime objectives of the Workshop were to demonstrate the use of space technology for health, and in particular landscape epidemiology; to share information on health-related activities and applications for Latin America and the Caribbean; and to discuss issues, concerns and approaches in developing e-health for the region, with the interest of establishing a network and stimulating the development of plans for e-Health implementation in the region.

The participants of the Workshop agreed to create a task force, “Panamerican Tele-Epidemiology Group” (PTEG). A permanent commission coordinates regional efforts i in unifying criteria and proposals for solution of common problems and in generating a regional alliance. The Group has been active in pursuing its goals since its initiation. Several key activities are as follows:

- Organized a dedicated Poster Session entitled “Space Technology as a Tool for E-health: Space Technology-Based Tele-Health Project Initiatives in Developing Countries” for the ISfTeH 2006

Med-e-Tel 2006 Conference held in April 2006 in Luxembourg. Presented 15 posters on e-health and telemedicine projects. Those projects were focused on the Tele-Health and Tele-Epidemiology applications in Latin America and the Caribbean Regions.

- Organized the "Health Workshop" during the XII Symposium of the Latin American Society in Remote Sensing and Geographical Information Systems (SELPER), held in September 2006 in Colombia. The Workshop was co-sponsored by the UN Programme on Space Applications. Twenty professionals from Argentina, Bolivia, Colombia, Chile, Ecuador, Mexico, Paraguay, Peru and Venezuela participated in the Workshop. They presented the concept and status of 13 projects on space technology applications to human health in infectious diseases. SELPER, financially supported by ESA, published a special issue on Remote Sensing and GIS Applied to Health, *ISSN 0717-2915*. It contains ten papers extracted from both the 2006 SELPER conference and the 2005 UN/ESA/Argentina Workshop.

- During the Health Workshop, the group was recognized as a Regional Initiative in Space Technology Applied to the Human Health, and it was officially denominated the Research, Application and Training Network on Space Technology Applied to Human Health --Tele-epidemiology Panamerican group. The objectives of the group were clearly defined and agreed upon, and a Coordination Committee was formed.

This book presents the regional initiatives on space technology applications to human health and a selection of on-going Latin American studies and projects on Telemedicine and Tele-epidemiology that were presented at the Med-e-Tel and SELPER meetings on 2006. Some of these projects were jointly conducted with universities and space agencies in Europe.

Each of the projects was categorized into one of 4 areas:

Area 1: E-health and tele-medicine: A public health service in remote and isolated areas;
Area 2: Space Technology applications for extreme environment and disaster response;
Area 3: Remote sensing-GIS to monitor the environment and local areas at risk;
Area 4: Space technology and infectious diseases.

The Regional Initiative in Space Technology
Applied to Human Health-
"Tele-Epidemiology Pan-American Group"

In the framework of the XII Symposium of the Latin American Society in Remote Sensing and Spatial Information Systems (SELPER), held on 26-27 September, 2006, in the City of Cartagena, Colombia, the Pan-American Group of Tele-epidemiology organized a "Workshop on Human Health" in response to the objectives and actions previously arranged by the same group in Argentina in September 2005. Twenty professionals of different areas related with Remote Sensing and GIS and with a common interest, the applicability of these technologies to Human Health, participated in the Workshop in representation of the following countries: Argentina, Bolivia, Colombia, Chile, Ecuador, Mexico, Paraguay, Peru and Venezuela. During the Symposium, objectives, recommendations and future actions of the group were well defined.and the group recognized as a Regional Initiative in Space Technology Applied to the Human Health and denominated **"Research, Application and Training Network on space technology applied to Human Health --Tele-epidemiology Panamerican group"**.

Background And Rational

The **"Research, Application and Training Network on Space Technology applied to Human Health --Tele-epidemiology Panamerican group"** was set up in September 2005 and it arose as a necessity to develop collaborative research and training performed by Latin American, European and USA scientists. These collaborative efforts are expected to led to the establishment of links among scientists of these countries, resulting in collaboration for research, application and training connected to Public Health problems endemic in the Region. The formal integration of the Network include training options to students and professionals considering the expertise of some groups, already in the Network, in space technologies and epidemiology such as space information, cartography, Landscape Epidemiology, remote sensing, climatic information and geo-statistic. A number of projects developed by these groups utilizes methods such as those used in **Epidemiological Surveillance** which are of great relevance to developing countries thus increasing the general usefulness of the Network activities.

The strategy applied from the very beginning to achieve the Network's objectives considers the improvement of the research-oriented training of junior Latin American scientists and public health professionals applying the general methods and using the capabilities already set up in the Institutions members of the Network. Support to research training (courses, stages, research oriented to M.Sc. and Ph.D. degrees) in the region, that should be compatible with international standards, is not only more efficient in cost/benefit terms, but, in addition, strongly decreases the risk of scientific emigration and increases the possibility for a real application of the new knowledge generated. This strategy should be implemented through a broad exchange of people (senior and junior scientists from the institutions involved) and information, directed to optimize the use of regional resources devoted to space technology application and research-oriented training. We should remember that the long time goal is to generate **Regional Health Early Warning Systems** supported by Space Technology.

Objectives Of The Regional Initiative In Space Technology Applied To Human Health

<u>General Goal:</u>

To reach a regional strength on the use and development of space technology applications to health allowing mitigation of emergent and re-emergent disease impact.

Specific Objectives:

- TO OBTAIN AND RECORD environment information, basic cartography and climatic information necessary for the development of Tele - Epidemiology.

- TO ENGAGE new human resources with a vision based on Landscape Epidemiology

- TO DEVELOP an information and image recording system for Regional use from remote sensing and geo-statistic.

- TO DEVELOP risk maps and Health Early Warning Systems, including Remote Sensing and entomology/ecology data, on regional pathologies and thematic areas that include diseases transmitted by: i) vectors (Chagas, Dengue, malaria), ii) rodents, iii) water iv) air and others.

- TO INTEGRATE this Tele-Epidemiology initiative in the National Program of the Ministry of Health of the countries members, considering the high operative level and strategic value of space technologies.

Recommendations

1. To stress the importance that this Regional Initiative and the support of UN/OOSA and PAHO will have for the latinoamerican countries as elements of support and guarantee giving continuity and sustainability to the group

2. To support and strengthen calls for the Tele-epidemiology initiative integration in the National Programs of the Ministry of Health of the countries members, considering the strategic value of these technologies.

It is considered to be fundamental:

3. The continuous support of the institutions included in the group so that this initiative can grow in a jointly form;

4. The political and technical commitment of government organisms to assume this initiative, rendering effective and sustainable such a decision;

5. The consolidation of technical-strategic teams in the different countries;

6. The creation of sub-regional technical teams for the follow-up and evaluation of the approved processes;

7. The participation of the national scientific institutions involved in epidemiology;

8. The catalytic support of UN/OOSA and PAHO as facilitators for experience exchange and permanent evaluation of the process;

9. The commitment of the institutions and space agencies in providing the needed information for the development of the technologies proposed in this initiative.

Action Plan

1. To develop a continuously updated database regarding the members of the group. The group should include at least 4 members from each participating country with 2 components from the health field and 2 from the geo-spatial one.

    1.1. To define the profile of new members joining the group
    1.2. To formalize the group (nomination of a coordination Committee and a group coordinator)

2. To set up a WEB portal for the group; the site should include information about the multilateral initiatives in course.

3. To promote the utilization of maps servers for publication of results and thematic layers of common use.

4. To promote virtual meetings via video conferences trying to achieve at least bi-monthly frequency.

5. To promote a continous and smooth communication of the group with reference international organisms (UN/OOSA - OPS) either for coordination of activities and for activities/project reporting.

6. To support the initiative of IG/CONAE in developing a six month-training program (within the context of shared projects) for the next years 2007 and 2008.

7. To coordinate and make possible further meetings of the group in the context of symposium already in preparation (Peru 2007 - Cuba 2008).

8. To promote the area of Tele - Epidemiology as an important topic to be developed by academics at a post -degree level (specialization, master) in the Region.

9. To promote bilateral or multilateral agreements between the institutions represented in the group for the development of specific joint projects.

10. To promote the development, at a medium term, of a joint project at a regional scale.

11. To conduct a systematic review of all the institutions working or that could work in the specific scientific area.

12. To study the socio-economic impact associated with the space technology utilization.

Ongoing E-Health
European and Latinoamerican Projects and Studies

In this publication it is presented a collection of scientific papers from Med-e-Tel and SELPER meetings organizing during year 2006 and which have been grouped according to 4 main areas:

AREA 1.- E-Health and Tele-Medicine: A Public Health Service in Remote and Isolated Areas.

The National Tele-health Program in Mexico. Amanda Gomez, Marcela Ramirez, Alberto Villagomez, Erik Garcia. Mexico

Social Connectivity, via Communication Platforms (the SAT/WiMAN-WiLAN/PC), Supporting Development of Local Capacities to Implement Health in Rural Small Localities of the Argentine Territory. Miguel Guillaumet, Marcelo Petrich. Argentina

A Portable Telemedicine Station. Fernando D. Balducci, German Hirigoyen, Rodolfo Ramirez, Argentina.

Cube-Sat, a Proposed Solution for the Lack of a Permanent Satellite Channel for Telemedicine Purposes in the American Region. Lilia Edith Aparicio and Juan Carlos Narvaez. Colombia

AREA 2.- Space Technology Applications for Extreme Environment and Disaster Response

Space Technology for Telemedicine in Extreme Environments and Disaster Response. S.W. Cone, A. Rafiq, R.S. Hummel, R.C. Merrell. USA

Telemedicine in Mobile Surgery. Edgar Rodas. Ecuador

River Health: Description of an Integral Healthcare Program in a Remote River Basin in Ecuador. Edgar Rodas. Ecuador

AREA 3.- Remote Sensing-GIS to Monitor the Environment and Local Areas at Risk

Remote Sensing-GIS to Predict on the Risk of Eutrophycation in Reservoirs. Claudia Rodriguez, Matias Bonansea, Florencia Bonatto, Viviana Reynoso, Carlos Prosperi, Miguel Mancini, Claudia Ledesma. Argentina

The Remote Sensing Perspective to Focus Landscape Ecology, the Anthropogenic Action and the Malaria Disease. L. Delgado, S. Ramos. Venezuela

Integral Evaluation of Malaria in Tuntunani (Bolivia) at 3800 m o/s. Aparicio Effen Marilyn Aparicio James, Rodriguez Jaime, Lima Edwin, Arana Ivar, Chavez Rimort, Halborsen Kjetil. Bolivia

GIS/GPS for Operational Strategies in the National Program of Control of Chagas Disease, Paraguay, G. Russomando, B. Paredes, E. Ferreira. Paraguay

AREA 4.- Space Technology and Infectious Diseases

Remote Sensing to Predict and Alert on the Risk of Waterborne Disease Outbreaks. Cristina Rodriguez, Maria del Mar Lleo and Christian Haag. Chile and Italy

Satellite Imaging Applied to Epidemiology: the Experience of the Gulich Institute in Argentina C. M. Scavuzzo, M. A. Lamfri, C. Rotela, X. Porcasi, E. Estallo. Argentina

Satellite-based Health Early Warning for Environmental Risks. Maria del Mar Lleo. Italy

CNES Strategy Towards Sustainable Services in Tele-health and Tele-epidemiology. M. Lafaye, A. Guell. France

Relations Between the Climate Variability and the Appearance of Dengue And Malaria Cases in Colombia (Elements For Its Prognosis), Jairo Alberto García Giraldo. Colombia

AREA 1

E-HEALTH AND TELE-MEDICINE: A PUBLIC HEALTH SERVICE IN REMOTE AND ISOLATED AREAS

The projects developing on this area aim to support the take up of broadband services in isolated and rural areas thus contributing to the brindging of the digital divide. Their objective is also to enable public services to contain costs and implement sanitary surveillance and prevention strategies in those areas where health services have difficult access.

The experience of the Mexican government and its effort in developing the National System e-Mexico, and one of its components, the Program of Action and e-health is presented in the first paper. Two other ongoing projects from Argentina and Colombia have as objectives to solve the lack of permanent and efficient communication systems by proposing satellite-based solutions to implement social connectivity and educational training. The difficulties in accessing health centers in specific situations would be solved by using mobile satellite-based solutions as proposed in another project from Fundatel Foundation from Argentina.

The National Tele-Health Program In Mexico

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[2] National Autonomous University of Mexico(UNAM)

Mexico has great extensions of land and its population has enormous socio-economical disparities. Interesting mortality and morbidity patterns are present which combine disease characteristic of developed countries with infectious diseases and other diseases related to poverty. Management of both groups of diseases require urgent involvement of the health authorities.

As in many developing countries in the world, people that live in remote rural areas have problems in accessing medical services. Mainly, these problems are due to geographic aspects and inaccessibility caused by inadequate roads and transportation infrastructure. They also include economic, labor and cultural aspects (1).

According to the Mexican Political Constitution, every citizen has the right to receive health care. Nevertheless, based on recent statistics published by the National Institute of Statistics, Geography and Informatics (INEGI), only 60.1 percent of the population has access to health services. These services are offered by social security institutions, such as the Mexican Institute of Social Security (IMSS), Institute of Security and Social Services for State Employees (ISSSTE), the Mexican Petrol Company PEMEX, the Marine and Defence Ministries (Secretaria de Marina y de la Defensa Nacional). The other 40.9 percent of the Mexican population lacks social security services, including health services. The Mexican Ministry of Health must provide health care to this open sector of the population.

The Mexican government has identify, as a priority of the Ministry of Health, the need for implementing the accessibility to health resources in our country. In general, there is an insufficient availability of hospital beds, particularly for specialized medical care. There also exist an inappropriate distribution of human resources dedicated to health, existing urban areas with an excess of health personnel and rural areas with human resources scarcity.

Within this context, it was planned in Mexico an ambitious program of public health, the National Program of Health 2001-2006. In 2000 the government also developed the National System e-Mexico, and one of its components, the Program of Action and e-health (2). The main objective of both programs aim to improve the level of health on the population and to extend the coverage and implement the quality of the health services. Priorities are the inhabitants of localities with high alienation levels and the use of technologies of information and telecommunications (TIC's) to provide medical care (3). **(Fig 1)**

The restricted telemedicine activities performed in Mexico mainly support medical education. A few telemedicine activities have been developed as pilot programs. Since 1995 the ISSSTE, which takes care of the 10.2 percent of the mexican population, carries out its own Telehealth National Program providing services only to the government employees sector. It is important to mention the priority of this program because it is the first telehealth program with a successful development by a government institution in Mexico (4, 5). **(Fig 2)**

The aim of this study is to analyze operative aspects of the public health institutions that support the need for improving telemedicine and telehealth activities within a National Telehealth Program. This National Program will provide integral health care including prevention, diagnostic, treatment and rehabilitation activities at the three levels of health care.

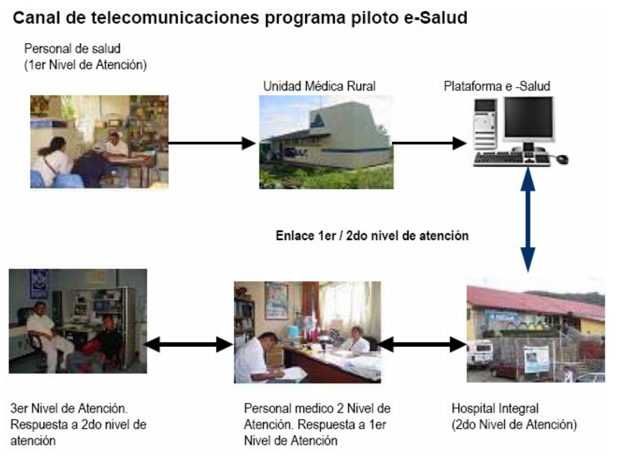

Figure 1. Telecommunication Channel In The E-Heatlh Pilot Program

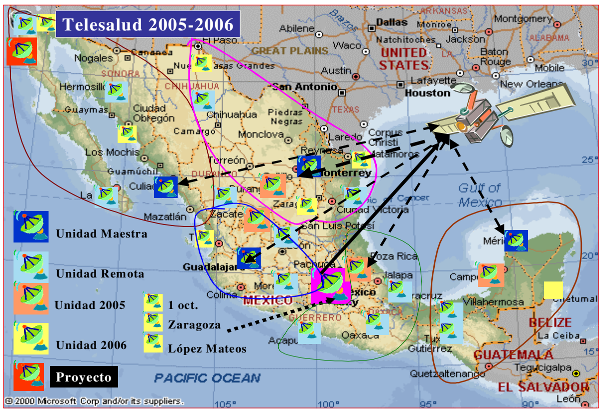

Figure 2. National Telehealth Program in 2th to 3th level of attention

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Social Connectivity, via Communication Platforms (SAT/WiMAN-WiLAN/PC), Supporting Development of Local Capacities to Implement Health in Rural Small Localities of the Argentine Territory

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I. INTRODUCTION

Era Digital Foundation, with its central place in Rosario (Santa Fe - Argentina) and through its Department of Investigation and Development, plans and executes a number of projects whose objectives prioritize communitarian participation, economic development, educative opportunities and improvement of health also considering the initial conditions of the scenario in which there will be developed.

Two of the projects in development have as a purpose the implementation of a platform of wireless communication in MAN - LAN networks by means of WiFi standard and access to Internet via a satellite route. Its appropriate convergence and integration represent an opportunity for education and development of local capacities to promote implementation of health care by Telehealth and Telemedicine.

II. EVALUATION PROTOCOL

The project "Evaluation of radio networks (WiFi / satellite) applied to platforms of telehealth" sponsored by –the International Development Research Centre (IDRC, Canada-Uruguay) and Centro de Investigación y Docencia Económicas (CIDE, Mexico) involves an axis of connection between the cities of Córdoba and Catamarca (Central-North-West provinces).

The project aim to highlight the need to develop and validate a protocol to evaluate objective and subjective conditions for the inclusion of these technologies in the existing health services. These services mainly target end users in reference hospitals and peripheral health centers of these provinces.

On the basis of the historical-social and ecological-environmental conditions, the protocol, evaluates four aspects: a) Institutional (i.e. organization, infrastructure, financing); b) Technological (Hardware, software, informational, communicational); c) Telehealth (knowledge, accesses, applications); and d) Health (personnel, services, benefits). In each one of them it is defined a series of aspects :

a) Institutional (impacts): costs-benefits, documentary registries, expectations, sensitivity, routine, satisfaction, investigation and development, ethical-political, public health.
b) Technological (updates): hardware/software and comm./Wi/sat - digital break, standards on the supported information and communication, manual and guarantees.
c) Telehealth (specificity): platform, incremental map, costs-benefits, utility (according to center / health service), applications, expectations, sensitivity, specific knowledge, professional formation (TIC and Telehealth), education, investigation and development.
d) Health (improvement – "more and better"): Users – population, social knowledge, cultural expectations, more frequent demands, regional epidemiologist, professional habitual "good-bad" practices, work conditions, social improvements - popular education.

Within each one of such aspects, joint complexes of variables have been delimited. After the analysis of possible methodological alternatives, it have been privileged and delineated to the date the following instruments:

1.- Tables for Documentary Analysis:
  (a) Centralized
  (b) By sector or aspect
2.- Guide of Observations (general)
3.- Guide of Interviews
  (a) Brief (20´)
  (b) Intermediate (30´)
  (c) Deep (50´)
4.- Guide of Group Dynamics
  (a) Initial (minimum: 30´)
  (b) Intermediate (minimum: 50´)
  (c) Extensive (minimum: 90´)
5.- Guides for Study on the field
6.- Guides for Observational Designs

(a) For pre-established situations or specific periods
(b) During daily passing of activities
(c) Controlled Observations - experimental Designs

7.- Questionnaire
(a) Boundary of real contexts
(b) Initial evaluation (present state)
(c) Intermediate evaluation (execution processes)
(d) Evaluation end stages (results)

All those initiatives are favoured by the current technological revolution and implementation of the communication with citizens, groups, institutions and peoples.

III. More Methodology Strategies

The other project entitled " Social Connectivity (hospital, schools, small companies, libraries) via communication platforms (the SAT/WMAN-WLAN/PC) in rural small localities of Argentine territory ", is sponsored by FRIDA Program - Regional Found for the Digital Innovation for Latin America and the Caribbean and supported by LACNIC - Latin American and Caribbean Internet Addresses Registry. In this case a partnership has been established jointly with National Technological University (UTN Rosario), the Federation of Telephone Cooperatives (FECOTEL Argentina) - Cooperative Telephone of San Gregorio (San Gregorio) and the Ecumenical Movement for Human rights (MEDH Rosario).

The project is developed in the small urban centers and rural areas of the Picasa floodable lagoons zone (South of the province of Santa Fe). This service, initially planned for the locality of San Gregorio, in this moment connects also its neighbouring: María Teresa, Diego de Alvear, Christophersen, Colonia Morgan; and others small communities with low availability of resources, small representation at the decision centers and excluded from the productive circle of the national market.

The digital inclusion of small localities is still problematic in a country like the Argentine Republic.

Even so, in Argentina, the province of Santa Fe (and other few areas) displays a number of good indicators in demographic, social, educational, sanitary and economic matters. As examples:

a) the existence of organizations with local involvement ability, and the presence of professionals and experts with commitment and ability of updating and training other citizens thus promoting interdependences between problems and possible solutions
b) the presence of organizations who could develop innovative projects like this and assure their future continuity thanks to a sustainable local management. They could also strengthen favorable links with other organizations such as the universities and favour convergences between social actors, public and private sectors and so on.

These new TICs are organized like a communitarian platform of connectivity to Internet, facilitating the access to more and better resources on/out of line. As a example, it is possible to identify the area of health: on-line resources, telehealth and second opinion, management of services, identification of health institutions, services and workers. In this context, the methodology strategies correspond to participative research procedures for educational and organizational aspects, quantitative strategies to control technological subsystems and quantitative-qualitative strategies for the follow up of the impacts of the platform on institutional awareness, professional good practice and strategies of social learning.

IV. Preliminary Conclusions

We consider that at present it is difficult to predict and generalize any conclusion. Marked differences among communities as regards health systems, demographic, social and cultural characteristics, access to health services, costs and resources might render these tools still hardly applicable.

A Portable Telemedicine Station

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Portable telemedicine applications have been enhanced by the enormous development of communication networks in our region, and with the decreased cost of mass store devices now available in our markets.

The prototype we are presenting here consist of a central processor which has a VGA video output and is connected to a TFT monitor. Both the operative and communication systems were implemented using USB devices. In this way, instead of a conventional hard drive it can be used a 1GB memory pen drive as support for the operative system and the developed applications.

Patient vital signals are captured using a DPS 56F8300 (Motorola). It is possible to configurate the software of the devices accordingly to the desired application (When switching on, the device ask the main station which parameters need to be configured, and then configures itself). Communication among patient units and central station is obtained via Bluetooth.

The same unit, mounted on an aluminium case of 50 x 30 x 15 cm, allows two configurations:

- As single diagnostic unit: with administrative capabilities, satellite positioning, and multiple connectivity (satellite, MODEM, radio VHF, mobile telephony, or WIFI). Currently a number of clinical laboratory instrumentation is under development in order to obtain portable diagnostic tools.
- As monitoring unit for emergency Intensive Care Unit, with capacity up to 16 patients

System configuration is fully preloaded in the pen drive, therefore, to choose a particular configuration the system needs only to be booted using the corresponding pen drive. The system can be also booted as a personal computer.

At present we are considering the possibility of using alternative energy sources, such as eolic or solar energy, to feed the unit.

Cubesat, a Proposed Solution for the Lack of a Permanent Satellite Channel for Telemedicine Purposes in the Latin American Region

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I. Abstract

This paper presents the design concept and some technological aspects of the ongoing project, "CUBESAT-UD" which stands for "Pico-satellite for Telemedicine solutions and Innovative Educational Projects", in the context of the educational projects developed by the Secretariat Pro-Tempore of the Fourth Space Conference of the Americas (SPTIVCEA), Colombia.

One of the projects generated in the framework of the SPT IVCEA activity has been the Cubesat program as a way to access space technology in the academic sector. The benefits of the program regards the possibility of training human resources in Science and Space Technology and of establishing an infrastructure with the capability of developing space activities. As a result, the Satellite Laboratory of the Distrital University has been designing and developing the Cube Sat Project since September 2005. Having as a mission telemedicine and telemetry activities, its goal is to establish a telemedicine payload between a virtual patient located on an isolated area and an specialist located far away. As an initial objective cardiology data from the patient have to be transmitted to the telemedicine center which will responde sending a tele- diagnostic. The SPTIVCEA is on head of Ministry of Foreign Affaires and its focal point is Civil Aviation of Colombia.

II. Introduction

One of the most important applications of space technology is the configuration of a satellite channel in order to bring medical services to isolated communities.

Latin American Region includes several areas located in the jungle and only accessible by a primitive ship called "chalupa". There is no possibility for a doctor to work on these areas. Therefore the only way to assist people is by telemedicine. As highlighted in a documents issued by United Nations OOSA (Office of Outer Space Affaires) developing countries are not promoting the use of space technology as expected to implement the quality of life of their communities because the lack of awareness of their decision maker authorities.

That is the reason why Colombia as SPTIVCEA (Secretariat Pro-Tempore of the Fourth Space Conference of the Americas) has been working on educational projects according to its plan of action. The SPTIVCEA is on head of Ministry of Outer Affaires and its focal point is Civil Aviation of Colombia. In consequence the focal point has been the leader of the Cube sat program in Colombia and Latin American [1].The project lets students learn how to develop satellites. The Cubesat is a Pico satellite of 1 kg of mass, cube shape and 1000 cm3.The Cubesat is designed by students and professor in the university and includes all the steps to develop a sixty millions of dollar satellite. Even the launching is included. The cost of the project is very cheap, maximum US$100.000; therefore achieving the project by a university is quite easy. The advantages of the project are: students learn "the know how" to build satellites and the University establishes an infrastructure where the satellites are built. This infrastructure is called laboratory. Moreover, The University can develop an aerospace program rendering the project sustainable. Students can place simple missions on Cubesats such as GPS, Telemetry, Telecommand and Telemedicine. Errors are welcome on these projects in that students learn through them.

Small satellites can accomplish many of the same functions of their larger counterparts at a fraction of the cost and design time, making them excellent for telemedicine data, quick-response science missions, ad hoc communication networks, component evaluation, and technology demonstrations. As a result, there has been an explosion in the amount of small-satellite projects. Indeed, many United States government agencies, including the Defense Advanced Research Projects Agency and the Jet Propulsion Laboratory, in addition to companies such as the Aerospace Corporation and TRW, are all working on small-satellite projects [2]-[5]. Capitalizing on this new interest, Professor Robert Twiggs and Andrew Kalman of Stanford University's Space Systems Development Laboratory developed the Cube Sat program for training students in the various aspects of small-satellite design, manufacture, and operation [6]. Design constraints include a mass no greater than 1 kg and a maximum volume of 1000 cm3.

The definition of the mission success criteria were defined in an incremental manner:

(1) Education of engineers and masters, practical experience with designing space system

(2) Acquire a signal from the satellite

(3) Acquire comprehensive housekeeping data for system evaluation

(4) Use the telemedicine data for scientific outreach mission and performance evaluation.

On the Cube Sat project, it is important to remember that it was constrained by: Short project (2 years from idea to launch), Very limited budget, Limited mass and power, Built by students with no prior experience with spacecraft design. The "CUBESAT-UD" will be completed in April 2007 and will transport to California Polytechnic Institute to undergo environmental qualification tests together with the other satellites to be deployed from the same deployment mechanism. From California it will be transported to Russia, where it was functionally tested and the batteries were conditioned before being launched.

III. SATELLITE DESCRIPTION

The satellite subsystems that are essential for operation makes part of the satellite system. These include the Power Supply Subsystem (PSS), Communications Subsystem (CS), and Mechanical Structural Subsystems (MSS), Attitude Determination and Control Subsystem (ADCS), along with the satellite's onboard Data Processing Subsystem (ODPs). The following paragraphs will describe an overview of the architecture of a pico-satellite.

In general for the electrical subsystems industrial graded components were used of the shelf. Some of the more critical components CPU's and MCU's have been tested to exposure of one year equivalent radiation dose.

In addition to these electrical subsystems the satellite consists of the structural subsystem, ODPS, PSS subsystems and a ground segment has also been developed for the project. The following paragraphs will describe each part in a little more detail.

A. Power Supply Subsystem (PSS)

The spatial autonomous system design requires a maximum efficiency as for the energy management: there are a simple calculus of power delivered to the system keeping in mind all the geometric factors and technical specifications of the components to be used. These calculations are based on the supplied power average requests by the design engineering team of the Cube Sat project. The objective of the system is to provide dependable power for all the modules of the satellite. Cube Sat UD, uses a system of basic power divided into the sections: solar Cells, Batteries, power distribution Unit, the circuits Latch-up and the Telemetry.

The main purpose of the PSS is to take power from the solar cells on the sides of the satellite and store it in the batteries as well as deliver it to the other subsystems of the satellite on a 5V power-bus and protect these users from latch-ups caused by radiation. The PSS consists of solar panels, electronics and batteries.

A conservative estimate of average input power is about 1.4 W. This power estimate constitutes one of the major constraints in the design and has been the driving force behind many design decisions.

The acquired energy is either consumed by the other subsystems or stored in the battery pack. The batteries are 4 Lithium-Ion polymer cells with a capacity of 940mAh each, giving a total capacity of almost 4Ah.

B. Mechanical Structural Subsystems (MSS)

The MSS team is responsible for the thermal stress and dynamic modeling of the satellite, as well as for the design and fabrication for all the support structures for the on-board components. The thermal modeling effort includes the development of a computer code written specifically to simulate heat transfer in the Cube Sat.

The numerical code features a hybrid resistance-capacitance finite volume formulation that accounts for heat transfer by conduction and external radiation as well as transient effects. The inclusion of internal radiation in the model is based on the resulting temperature gradients and a resistance criterion. The numerical analysis is then used to optimize the thermal design, which is based on the restrictions of the electronic components.

C. Communications Subsystem (CS)

The main purpose of CS is to receive signs of telemetry of the satellite like internal, external temperature, quantity of light, temperature of batteries, load of batteries, GPS, space in memory, data of 5 electrocardiograph signal for passing. It is composed by: Transmission and reception antenna, Rotor with their control system (RS232 ProSisTel), azimuth system and elevation model (PST75-12 ProSisTel), Computer - PC (YOU: XP), GPS System Tyco marks model Electronics A1021 with its external antenna.

Ground Station: the main part is the antenna, WX-706 from RF-connections was chosen. This is a 2X18 element crossed Yaggi directional antenna, with a gain of 14 dB. Since this is to small a gain to uphold the requirements of 15 dB, two of them where acquired and set up in a parallel configuration, as can be seen and thereby raising the gain with 3 dB and ending up with a total gain of 17 dB. The Figure 1, shows the sketch communication subsystem.

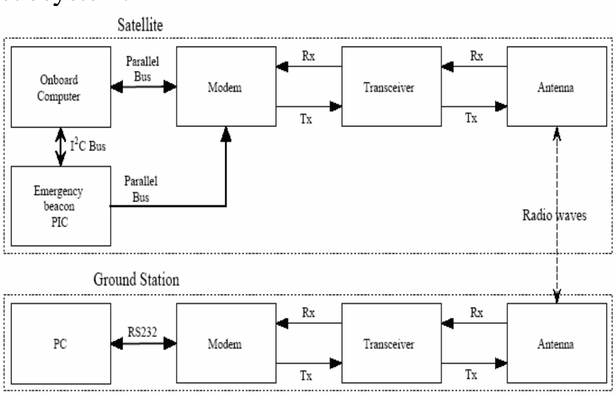

Figure 1. Sketch Communications Subsystem

The FSK-ASK Transceiver is ADF7020 433Mhz. The Receptor it includes the whole hardware, filters, amplifiers, Used etc. to carry out the transmission and reception of the radio signs in the antenna, the hardware should operate half duplex, the transceivers are programmed in the uplink frequency 433 Mhz and Down Link 915 Mhz

Receiving ground station Down link, for the station can serve the radii in 915 of micro hard Spectra 920 - Enclosed Wireless Modems, but if it is possible to find radios for earth with sensibility of -121 dbm, it would be is better.

The antennas are mounted on a tower and by the help of two motors they can be turned both around and up-down and this is controlled by the PC. A

D. Attitude Determination and Control Subsystem (ADCS)

The objective is to provider a positioning global system, it is composed by: Sensor Systems, Biaxial Magnetics,3-Axial Inertial Correction System, Diffused Micro controller System, Tyco Electronics GPS A1021, low power, weight and size reduced.

E. Onboard Data Processing and Control Subsystem (ODPCS)

This is the, interface between the communication subsystem and the micro controller, data mission, power control, temperature sensor, position control, diagnosis control of solar panels. It contains: principal processor, micro controller MSP430, CPU de 16-bits RISC technology, 3.3Mhz clock, 16KB in memory, RAM 512, Communications input/output ports, 3.3 – 5.0V operation voltage. Development software is Salvo Pro RTOS and development tools are Cross Works for MSP430 de Rowley Software. The Figure 2, contains a description on this subsystem.

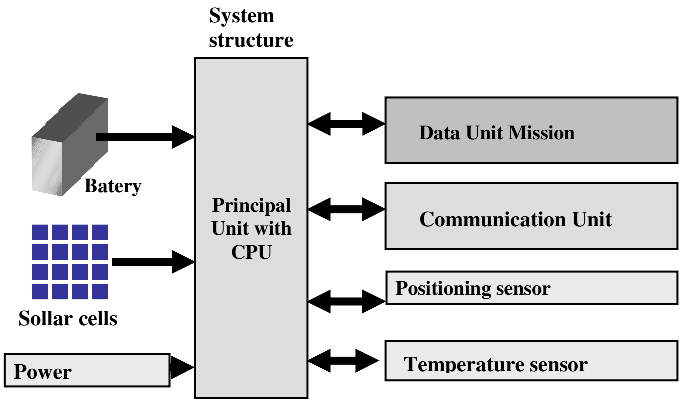

Figure 2. Sketch Communications Subsystem

IV. MISSION PAYLOADS

The Distrital University's CubeSat project is able to accommodate two separate payloads, despite the 1-kg weight limit. The main payload consists of an experimental telemetry and the second is telecardiology for telemedicine research.

Current CubeSat communication systems operate in the VHF/UHF range, which may not be able to accommodate future, data-intensive CubeSat missions such as the lunar and Mars missions in 2006-2007 [7]. Then it is very important to develop research to qualify engineers in development of satellites for terrestrial solutions.

The second mission will deal with a telecardiology system in the terrestrial portion of the system where CubeSat will be used to transmit compressed data to other remote regions to provide services of basic attention in health. The telecardiology system is presented in references [8], [9] and it has been tested in internet.

Also and between the secondary objectives it will be studied the possibility to implement a KatySat Mission.-Kids are not too young for satellites [10], [11]. For example, the establishment of worldwide audio broadcasting that joint with Ground Station at some Colombian Schools will let K-12 Education on Science and Space Technology. This project was born in Stanford University and "CUBESAT-UD" team will support the KatySat Team in some aspects.

VII. EDUCATIONAL PROGRAM

The Distrital University has been started a new educational program in the Master of Science in Communications and Information System with the former students in Satellite Networks where the cube sat program is the first experiment to be developed: Its study plan includes five specific modules on satellite networks and the laboratory is the support to develop research in this area.

VIII. CONCLUSION

In conclusion, the CubeSat project has achieved three major results: Primarily a large group of students will leave the university with a great deal of ”Hands-on experience” within satellite design and experience working in a large project that requires cooperation among all the participants involved. Moreover,,the development of small satellites will allow countries that have not been immersed in these scientific fields to access a space career; finally, it is important that the satellite system provides facilities for solving social impact problems as those corresponding to the health field.

IX. ACKNOWLEDGMENT

We would like to acknowledge the Civil Aviation of Colombia, Ministry of Foreign Affaires and Social Protection Ministry at Colombia, California Polytechnic Institute and Stanford University at USA.

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AREA 2

SPACE TECHNOLOGY APPLICATIONS FOR EXTREME ENVIRONMENT AND DISASTER RESPONSE

Remote or extreme environments are characterised by their location and the hard nature of their surroundings. In these places, the ability to reach medical resources, whether it be for guidance or tertiary care, are challenged significantly. This can be further exacerbated when distance and a lack of communication capabilities is a factor. Examples include ships at sea, remote and isolated areas or, in some cases, places isolated as a consequence of a natural or man-caused disaster. The challenges of most importance in extreme environments include distance, communication, culture, language and technology. Prior to implementing any change, new technologies or processes, there must be a complete understanding of what the needs are, the definition of requirements and the setting up of an appropriate system to meet needs and expectations. In this field, satellite technology would play a major role with its large coverage allowing equal access and its independency from extreme meteorological events leading to ground communication structures interruption or malfunctioning.

Ii is presented, in this area, two examples on the use of satellite in remote, inaccessible zones in the Ecuador jungle currently in use: in the first case, satellite supports mobile surgery helping in the pre-operative evaluation, telementoring and teaching during the operation and for post-operative follow up; in the second case, satellite technology is used to determine river conditions to help in assessing operability and safety of a mobile medical fluvial unit.

During times of disaster, healthcare and communications systems may be adversely affected and reduced to levels considered substandard in the developed world: an USA- Fundación Cinterandes project on this area highlight the possible application of space technologies developed for extreme environments to provide a means of support in case of disaster.

Space Technology for Telemedicine in Extreme Environments and Disaster Response

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USA

I. Summary

We report the use of space technology, especially satellite communications, to validate telemedicine systems for use in remote environments.

II. Background

The developing world has a number of barriers to effective healthcare information sharing in remote areas. Among the barriers are limitations in reliable means of transmission, and the dynamic nature of most connections. For many years, NASA and other space agencies have recognized the need to overcome similar barriers in caring for the space explorers' healthcare needs [1]. To these ends, our group has investigated the use of radio, telephone, and satellite transmissions for use in the integration of the primary and secondary health services in remote areas of Ecuador (with applicability to space and other remote locations) [2-13].

These solutions using space technology, while designed to support space agency missions, also provide useful solutions to areas with communications problems on Earth. As demonstrated in Figure 1, these solutions enter a cycle of development and validation, both terrestrially and in space, and usually help both the intended recipients and the test subjects. We have developed solutions for medical support in extreme environments, of various capabilities, using various communications modalities.

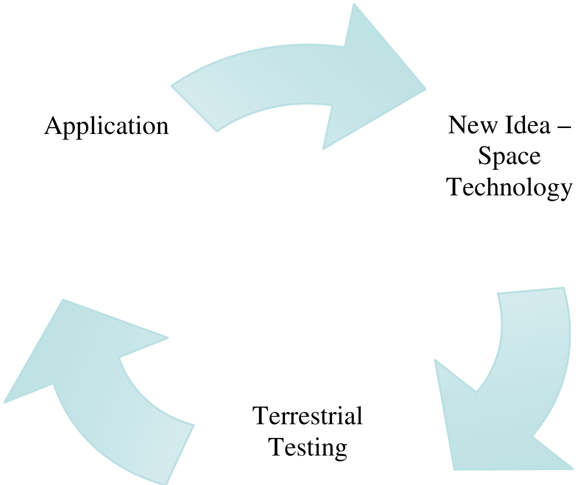

Figure 1. Creative flow for Space Technology, involving terrestrial testing and application.

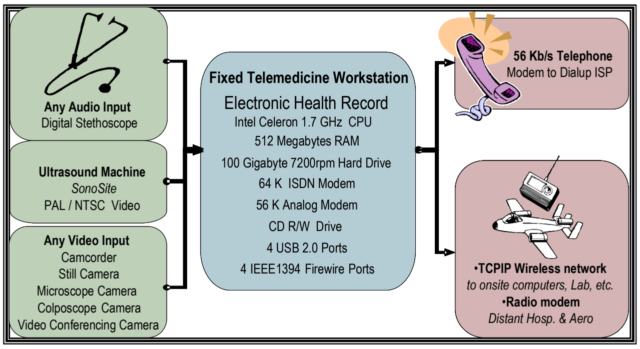

Figure 2. Telemedicine Workstation Setup, with multiple input and output devices.

III. Materials and Methods

A. *Multimedia Telemedicine Workstation*

We developed a multimedia telemedicine workstation, as in Figure 2, which would incorporate various forms of data, video and still images into a coherent, longitudinal electronic health record [14]. The electronic health record was developed using Microsoft Access © (Redmond, WA). Other components of the system were based on off-the-shelf technology, keeping the total cost ~ $1200 USD.

The telemedicine workstations were placed in four sites in various provinces of Ecuador, three primary care facilities, and one surgical specialty (Fundación Cinterandes).

B. Radio Communications

Radio communications have long provided a means of voice communications in terrestrial areas without other services, and in times of breakdown of standard telephone communications. Radios may also provide a means of data transfer, and, even image transmission – though at extremely slow speeds.

C. Plain Old Telephone System (POTS) Communications

Telephone modems have become standard equipment for most computers today, with speeds of 56 Kbps, at best.

D. Satellite Communications

We have used the InMarSat B portable satellite telephone system, with 64 Kbps Integrated Services Digital Network (ISDN) modem for data transfer. We transmitted surgical cases with real-time video using two identical InMarSat phones connected in series, for 128 Kbps total transmission speed. We have also performed teleanesthesia using only one 64 Kbps InMarSat phone.

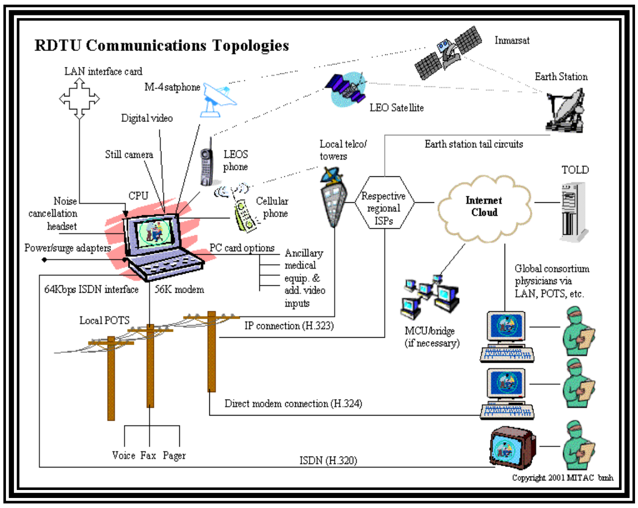

Figure 3. Multiple communications modalities available for use with the RDTU.

E. Rapidly Deployable Telemedicine Unit

We have developed the Rapidly Deployable Telemedicine Unit over many years, honing to its present configuration and capabilities. Current communications modalities are displayed in Figure 3.

IV. Results

Radio, today, still provides an adequate means of communicating by voice with distant sites. Though we have used this system for data, even image, transfer, this method proves much too time-consuming for practical application.

In truth POTS communications may be limited by local Internet Service Providers (ISPs), commonly only providing 22 Kbps in Ecuador. Yet, this has proven to be adequate for most store-and-forward applications in place [3;8], with some limited videoconferencing (low resolution and pixelated).

Satellite connectivity generally provided adequate bandwidth for all applications. Real-time transmission (at 128 Kbps) of high quality video images during surgery, with distant confirmation, has been demonstrated [15]. Anesthetic monitoring has been accomplished with half that bandwidth, with full real-time transmission [4].

V. Discussion

During times of disaster, healthcare and communications systems may be adversely affected and reduced to levels considered substandard in the developed world. In these instances, such as in response to the Hurricane Katrina disaster, lessons learned from our work in remote, extreme environments helps provide a means of support and otherwise nonexistent connectivity.

The technical solutions available are as varied as the barriers to be overcome and the populations in need.

VI. Acknowledgment

The authors wish to thank the Fundación Cinterandes and the Clínica Luxemburgo for their valued years of assistance with our collaborative efforts in Ecuador.

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Telemedicine in Mobile Surgery

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We have used telemedicine to support our Mobile Surgery program. For a period of 11 years, we have been operating in the Ecuadorian Amazon Jungle and the high slopes of the Andes and Pacific coastal plains.

On a 24 foot Isuzu van a mobile surgical unit (MSU) was installed. We could have used more space, but a bigger vehicle would have been difficult to maneuver through the winding and narrow Andean roads. We use two tents, one for patient preparation and another for patient recovery

During the 11 years period, we have performed more than 5.000 operations, with excellent results, great patient acceptance, no mortality and a very low complication rate.

In the last 6 years we have used Telemedicine for pre-operative evaluation; during the operation for telementoring and teaching; for post-operative follow up and for consultation of primary care family physicians.

I. TELEMEDICINE FOR PRE-OPERATIVE CONSULTATION

When we travel to a remote site with our Mobile Surgery program, the first day is devoted for patients preoperative evaluation. This time-consuming endeavor can be shortened in different ways.

The simplest way we have used, is to receive, in advance, the list of patients with their age, diagnosis and any additional problems they might have. Then, we discuss the case by telephone with the primary physician and suggest laboratory and image tests and pre-operative preparation.

An additional advantage is the electronic transmission of the patient's records and the picture of the lesion, for instance, a visible tumor or a hernia. Pictures of image results, X-rays films or ecosonograms can also be transmitted. All what we need is a computer at each end of the line, a digital camera, access to Internet and adequate software.

There is a limitation with these methods: the lack of interrelation with the patient. We have overcome this problem using in the remote place, a laptop computer equipped with telemedicine software: Distant Care, Microsoft Outlook and Microsoft NetMeeting. At the base station there is a desktop computer loaded with the same programs. Distant care is used to establish the connection between the two computers. Distant Care and Microsoft Outlook manage patient records and digital storage and transmission. Microsoft NetMeeting makes possible the interaction between the patient in the remote place and the surgeon at the base station.

II. TELEMEDICINE DURING THE OPERATION

Telemedicine, during the surgical procedure, has been used for telementoring and for teaching a distant audience.

Telementoring is the guidance of a less experienced surgeon operating in a remote site using telemedicine in real time. Our first experience was in May 1998. Using the existing telephone lines, a laptop computer was set up next to the laparoscopic viewing monitor. Using Distant Care software, a connection was established with the Endo-laparoscopic Center at the Yale University. Telemontoring took place during a laparoscopic cholecystectomy performed by a surgical resident at the MSU.

Lately, with the active participation of the Virginia Commonwealth University (VCU) and Medical Informatics and Technology Application Consortium (MITAC), several interaction activities between the MSU in the Amazon Jungle and Richmond VA., have taken place. Telementoring sessions and teleanesthesia or distant monitoring of anesthesia procedures have been successfully accomplished.

Interaction between the Mobile Surgical Unit in the countryside and the base station at the Cinterandes Foundation in the City of Cuenca has been established. Medical students have been able to follow the steps of different surgical procedures and correctly identify anatomical structures (Kbps)-satellite communication connection. Consultants in Richmond and Surgeons in Ecuador agreed in the identification of surgical landmarks.

III. TELEMEDICINE FOR POST-OPERATIVE CONSULTATION

The technology and the principles used are similar to those used for preoperative consultation. We need a phone line, access to Internet, a videoconference camera, a digital camera, audio system and adequate software.

Images of the healing wounds were transmitted and diagnosis of normal healing or complications was accomplished. Presence of congestion, edema, infection and skin marks due to reaction to tape, were clearly identified. (3)

IV. CONCLUSIONS

We believe that telemedicine is an excellent complement for mobile surgery. Pre-operative consultation saves precious time that can be spent in the operating room once we arrive in the remote place. Having an advanced knowledge of the types of surgeries we need to perform, we can make an accurate appraisal of supplies and medicines we need to take with us.

The surgeon and anesthesiologist feel much more comfortable if they know patients and their problems in advance. And, first of all, the patients feels much better if they have interacted with their doctors before the operation

.

Telemedicine permits us to maintain contact with our patients until their complete recovery, overcoming one of the main problems of intermittent mobile surgery.

Telementoring, for us, is in the initial phase. The operating team, being mentored, has always had the capability to solve the problem by its own means. There has always been an agreement with the consultants about identification of anatomical landmarks and surgical steps to take. Nevertheless, we are aware that there are situations in our country and in many places in the world, that a patient does not have access to an experienced surgeon and teleconsultation and telementoring might solve desperate situations and save lives.

Demonstrating anatomical structures and surgical procedures to students seating comfortably in front of a video screen, has been more effective thanlooking over the surgeon's shoulder, trying to get a close view and maintain at the same time enough distance, in order not to contaminate the operating field.

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River Health: Description of an Integral Healthcare

Program in a Remote River Basin of Ecuador

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I. Abstract

The province of Morona-Santiago is probably the most isolated in Ecuador; furthermore, its Eastern zone has practically no roads, and the only means of access is by small aircraft to rudimentary airports in the jungle. The villages are linked through a rich network of rivers. The health situation is appalling and healthcare is precarious. Malnutrition, parasitism, tuberculosis, malaria, hepatitis and other diseases are prevalent. Therefore, we believe it is necessary to organize a fluvial healthcare unit in coordination with fixed health posts as a system to deliver health to the area.

In April 2001 navigation of the main river, Morona and its effluents by motor powered canoe was completed in an attempt to chart the river path by GPS, and to determine adequacy of depth and width throughout the watercourse. Agreements were signed between the central and local governments, private companies and NGO's for the financing, construction, equipment, administration and execution of the project.

We have been offered to utilize satellite technology to determine river conditions to help in assessing operability and safety of the fluvial unit.

A multidisciplinary team in conjunction with the natives will elaborate a model of development for the area with minimal infringement of the fragile Amazonian ecosystem. The integral health program will include: health information gathering, immunization, growth and development, prevalence diseases of infancy and school aged children, sexual health and reproduction, geriatrics, oral and mental health, education for basic sanitation, and compilation of traditional knowledge regarding medicinal plants and their application. We will also have intermittent surgical brigades 3-4 times a year. To facilitate the implementation of the program we will make use of Telemedicine for consultation and support from the CINTERANDES foundation headquarters in Cuenca and MITAC in Richmond, Virginia.

The results of our efforts so far have accomplished the foundation on which the program will build on. We produced an accurate map of the river conditions in conjunction with the location of the villages. The extension of traversable river is approximate 100 Kms, with an estimated population of 5,000-10,000. The fluvial unit was built in Ecuador and contains an operating room, recovery room, a consultations office and living quarters. It is capable of negotiating the charted channels. We anticipate the project will be activated in mid 2006 and its results will be reported thereafter.

KEY WORDS: River Health, Healthcare, Integral Health, and Telemedicine.

II. Introduction

Of the 22 provinces that make up Ecuador, Morona-Santiago located in the nation's southeastern region is probably the most isolated in Ecuador; furthermore, the area east of the Cutucú Andean mountain range has practically no roads, and the only means of access is by small aircrafts which have to land in rudimentary airports in small clearings in the dense jungle. In the remote river basin of the Morona River numerous small primitive villages are linked through a rich network of waterways.

The health situation in these rural communities is appalling and healthcare is precarious at best. National health statistics indicate that malaria, malnutrition, parasitism, tuberculosis, hepatitis and other diseases are prevalent. However a database that reflects the true state of health and necessities of the population in this region is deficient. Due to its remoteness, development of the area has been relegated. Therefore, we believe it is necessary to organize a healthcare and human development program that will have a fluvial unit in coordination with fixed health posts located throughout the river basin as a system to assess and deliver healthcare to the area.

III. Project Conception

The CINTERANDES Foundation has been providing surgical services to many remote areas in Ecuador since 1994 by means of a Mobile Surgical Unit [1]. We have excellent outcomes, with low complication rates [2] (see table I), and in a cost-effective manner [3]. An advantage of this model is that patients are cared for in their own environment with the active participation of the community. Our work captured the attention of a missionary who lived in the province of Morona Santiago and knew in detail the living conditions and necessities of the villagers.

COMPLICATIONS	NUMBER (PERCENTAGE)
Deaths	0 (0%)
Cardiac arrest	2 (0.04%)
Pulmonary embolism	1 (0.02%)
Colonic injury	1 (0.02%)
Bladder perforation	1 (0.02%)
Bleeding	
Slight	15 (0.30%)
Moderate	27 (0.54%)
Severe	2 (0.04%)
Infection Rate	
Clean cases	24 (0.49%)
Clean contaminated cases	124 (2.48%)

Table I. Surgical Complications in Mobile Surgery

IV. INITIAL STEPS

In April 2001 a team of the CINTERANDES Foundation and MITAC traveled to this remote area and navigated a section of the Morona River and its tributaries by means of motor powered canoes. Utilizing a GPS unit the watercourse was charted, and determination of the adequacy of depth and width throughout the river was determined. The extension of traversable river is approximate 100 Kms, with an estimated population of approximately 10,000. After determining the negotiability of the rivers and plotting village location in our river chart we developed a proposal that was reviewed and approved by the Ministry of Health.

For a healthcare system to work in this environment and be sustainable for the foreseeable future, involvement of beneficiaries, central and local governments, private companies and NGO's had to be integrated. An agreement was signed between the different parties for the financing, construction, equipment, administration and execution of the project [4]. The following institutions are participants in the project: the Ministry of Public Health, MODERSA, and the Healthcare Department of Morona Santiago, PETROECUADOR, the Provincial Council of Morona-Santiago, ECORAE, and the CINTERANDES Foundation which will be in charge of the supervision and execution of the project, as well as to carry out the surgical brigades. MITAC will provide support for the telemedicine component.

V. THE FLUVIAL UNIT

The Fluvial Unit was built in Durán, Ecuador; it is 18 meters in length, 4.5 meters wide, 2.1 meters tall, with 0.4 meters of draught. It contains an operating room, recovery room, a consultations office and living quarters. The unit was delivered by land to Puerto Morona, a village that has access by a dirt road where it will be fitted with the necessary equipment.

VI. INTEGRAL HEALTHCARE PROGRAM DESIGN

The specific objectives of the Integral Healthcare Program include:

1) Health information gathering. 2) Complete primary care services for the area of Morona River basin and its main tributaries. 3) Perform intermittent surgical brigades. 4) Conduct a study of the main health problems of the area. 5) Define in conjunction with the population and a multidisciplinary team a model of human development in harmony with the Amazonian ecosystem.

Figure 2. "TSUNKI NUA" Fluvial Unit.

The Primary health team will be composed of 2 physicians, a nurse and a dentist. This health team will navigate the Morona River and tributaries 3 weeks of each month depending on river conditions. The integral health program will include: immunization, growth and development, prevalent diseases of infancy and school aged children, sexual health and reproduction, geriatrics and rehabilitation services, oral and mental health, education for basic sanitation, and compilation of traditional knowledge regarding medicinal plants and their applications (see table II).

COMPONENTES OF INTEGRAL HEALTHCARE PROGRAM
Information gathering
Immunization
Growth and development
Prevalent diseases
Sexual health & reproduction
Geriatrics
Rehabilitation services
Oral health
Mental health
Violence, alcohol & drug prevention
Education in sanitation
Traditional knowledge compilation
Surgical missions

Table II. Integral Healthcare Program

VII. SURGICAL COMPONENT

It has been our experience that owing to surgery's dramatic effects and our positive outcomes, it has allow us to gain trust and credibility, and consequently facilitate the implementation of other healthcare programs that have greater impact in those communities. Therefore, we will carry out intermittent surgical brigades 3-4 times a year, and at the same time we will provide consultation by university physicians and will assist in the data collection and analysis.

VIII. SATELLITE TECHNOLOGY

Although the Morona River confers an effective passageway into these remote villages, the navigational hazards associated with changes in water levels may constitute an inconvenience. We have been offered to utilize experimental satellite technology for hydrologic forecasting to determine river conditions, and aid in the assessment of operability and safety of the fluvial unit. Updated forecasts of river flow conditions could be made available via telecommunications to the CINTERANDES Foundation.

To facilitate the implementation of the program we will make use of Telemedicine for consultation and support from the CINTERANDES Foundation headquarters in Cuenca and MITAC in Richmond, Virginia. From previous experience with telemedicine we have demonstrated its capabilities in the pre-operative evaluation, and in post-operative patient follow-up as an invaluable tool that can breach the distance of remote and isolated areas [5,6].

IX. CONCLUSIONS

The results of our initial efforts have accomplished the foundation on which the program will build on. It is feasible to navigate the Morona River with a fluvial unit that can carry out an Integral Healthcare Program in coordination with fixed healthcare posts.

Joint efforts of the public and private sector have conceived a comprehensive healthcare program that could be exploited as a model for future projects in similar conditions.

Satellite technology can give support in hydrologic forecasting to help determine navigability of the fluvial unit. Telemedicine can be effectively used to provide support and improve patient care. We expect the program to be activated in mid 2006.

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AREA 3

REMOTE SENSING-GIS TO MONITOR THE ENVIRONMENT AND LOCAL AREAS AT RISK

The operational use of remotely sensed data for large scale monitoring of environmental indicators uses sequences of consistently calibrated and standardised satellite imagery. Several spatial scales need to be considered for effective monitoring: the natural scale of the processes involved or the state reflected by an indicator; the scale or resolution of the remotely sensing instrument; and the reporting scale. A large number of environment indicators can at present be monitored by satellites and among these vegetation cover and related aspects, vegetation and bare ground, specific chlorophyll detection, suspended sediments, soils and erosion, urban land use and fragmentation, land and sea surface temperature. Integration of satellite imagery with geographic information systems (GIS) helps in localizing the monitored areas thus allowing an environmental quality evaluation over time and the precise location of specific areas at risk.

In this publication we present a number of ongoing projects in which space technology and GIS are used to evaluate the eutrophication state of a specific area, to detect and localize rural areas at risk for malaria and as a support in a National Program for Chagas disease control to precisely identify and localize places subjected to vector disease de-infestation.

Remote Sensing –GIS to Predict on the Risk of Eutrophication in Aquatic Systems

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I. Abstract

Lakes and dams are exposed to environmental degradation, and their low renovation time makes some of them vulnerable to pollution as a result of anthropogenic impacts. Main objectives of this study have been the possibility of predicting the quality of water for different uses and the evaluation of the eutrophication state in dams of central Argentina. We have used physico-chemical, biological and phycological analysis, integrating remote sensing and GIS in order to asses potential risks for animal and public health. The first (Río Tercero, 64º 23'W y 32º 10'S; 4600 ha) and the last (Piedras Moras 32º 12'S, 64º 19'W; 832 ha) dams in the basin of Ctalamochita or Tercero River were studied. Both are used as reservoirs for drinking water, hydraulic engineering, irrigation and recreational and sports activities. Seasonal samplings were performed during three consecutive years in both sites. Parameters were evaluated in situ and in the laboratory, according to standard methodology. For Rio Tercero dam, water characteristics were those corresponding to freshwater, calcium bicarbonated. Trophyc status was mesotrophyc. Phycological counting showed that, during summer, Bacillariophyceae were dominating over Cyanophyceae. The studies integrating sensors, GIS and Landsat 5TM images to determine spatial variability of chlorophyll-a showed a higher concentration at the affluent during spring time. For Piedras Moras dam, the application of Surfer for Windows, Idrisi and Variowin was used, integrating in a GIS the experimental information together with the one obtained by means of digital processing of Landsat 5TM images. The application of spatial interpolation techniques -kriging- demonstrated that dispersion of total nitrogen was different according to the season. Total phosphorous during spring showed its higher levels at Soconcho River and Balneario stations. Maximal levels of chlorophyll-a were observed in spring at those stations corresponding to affluent and recreational areas. The state of studied dams is within the range established in the the guidelines proposed by actual legislation. Blooming could happen all over the year but the risk diminishes during fall season. Because of the importance of these systems, it is necessary not only their monitoring to evaluate and protect these reservoirs but also to establish a global program of strategies for the prospective management of dams in order to determine risky areas and early warning systems to protect health.

KEY WORDS: Water quality, remote sensing, eutrophication, public health

II. Introduction

Argentina has a wide territorial extension of about 2.700.000 km^2. Lakes and dams are exposed to environmental degradation and the low renovation time of some of them, makes them vulnerable to pollution as a result of anthropogenic impact.

The excess of organic matter modifies the natural chemical composition of the water, with an increase in primary production [1] [2]. When high levels of eutrophication are reached, algae are among the best bioindicators of pollution and some of their blooms may be hazardous both for animal or human consumption.

III. Objectives

Main goals of this study have been to analyze the possibility of predicting the quality of water for different uses and the evaluation of eutrophication in reservoirs of central Argentina by means of physico-chemical, biological and phycological analysis, integrating remote sensing and GIS in order to asses potential risks for animal and public health.

IV. Materials and Methods

The first (Río Tercero, 64º 23'W y 32º 10'S; 4600 ha) and the last (Piedras Moras 32º 12'S, 64º 19'O; 832 ha) reservoirs in the basin of Ctalamochita or Tercero River were studied. Seasonal samplings were performed during three consecutive years in both sites. The lakes are used as reservoirs for drinking water, hydraulic engeneering irrigation and recreational and sports activities. Seasonal samplings were performed during three consecutive years in both sites. Parameters were evaluated *in situ* and in the laboratory, according to standard methodology. The first has 46 km2, with a maximum of 560 hm3 and a production of 58000

Mwh/a. Piedras Moras dam has 832 km2, with 90 hm3 and 46000 Mwh/a.

For physico-chemical analysis, the samples were collected at 20 cm depth and the parameters evaluated were smell, turbidity, colour, temperature, pH, dissolved oxygen, conductivity, chlorines, sulfates, bicarbonates, alkalinity, arsenic, BOD, COD, total nitrogen and total phosphorus [3].

For algal studies, the samples were collected in the same way and fixed in formalin 3%. The identification of the organisms was made under optic microscopy, by means of identification keys, and direct counting was expressed as cells per 25 ml. Chlorophyll a was measured by photocolorimetry [4].

V. MAPPING CHLOROPHYLL A AND NUTRIENT

In this study a GIS package (Envi ver. 3.5) has been used. Water samples were collected from various sites inside the Rio Tercero reservoir. To accurately mark the location of the sampling station inside the lake, a GPS was used.

The chlorophyll model was applied on the band 2 and the band 4 image of the lake [5] [6] [7]. For Piedras Moras reservoir, Surfer for Windows, Idrisi and Variowin were used, integrating in a GIS the experimental information together with the one obtained by means of digital processing of Landsat 5TM images.

VI. RESULTS

For Rio Tercero dam, water characteristics were those corresponding to freshwater, calcium bicarbonated. According to this result, Rio Tercero dam is considered to be mesotrophic. Piedras Moras dam is instead eutrophic to hipertrophic (Table I and Table II).

TABLE I
LEVELS OF NT, PT, N:P AND CHL A. SUMMER. RIO TERCERO.

Parameters	Unit	Sampling stations*					
		1	2	3	4	5	6
Secchi disk	(m)	0.55	1.15	2.9	2.45	3.1	0.7
Total nitrogen	(mg/l)	0.7	0.6	0.6	0.6	0.6	0.6
Total phosphorus	(mg/l)	0.02	0.02	0.02	0.02	0.02	0.02
N:P	(mg/l)	35	30	30	30	30	30
Chl a	(µg/l)	31	14	9	5	7	6

*Average value

TABLE II
ALGAL DISTRIBUTION IN RÍO TERCERO DAM. SPRING (nº cells/25 µl).

	SAMPLING STATIONS 1	2	3	4	5	6	7
Cyanophyceae							
Microcystis aeruginosa	-	-	1	2	-	-	-
Anabaena spiroides	-	2	-	1	-	-	-
Lyngbya aerugineo-coerulea	1	12	1	-	-	-	-
Phormidium uncinatum	-	-	-	-	-	-	1
Chroococcus	3	-	30	1	10	-	24
Merismopedia sp.	-	1	-	-	-	-	-
Bacillaroficeae							
Melosira granulata	-	14	8	25	17	-	5
Cyclotella sp.	2	-	-	23	19	-	10
Otras	50	32	41	30	29	-	13
Euglenoficeae							
Euglena sp.	-	26	23	-	-	-	1
Zygoficeae							
Cosmarium sp.	-	1	-	-	-	-	-
Chlorophyceae							
Pediastrum duplex	-	-	1	-	1	-	-
Selenastrum sp.	-	-	-	-	1	-	-

1. Quillinzo river and La Cruz river
2. Cooling channel
3. Centre of the lake
4. Villa Rumipal beach
5. Hotels
6. Villa del Dique entrance
7. Dam

- Absence in the sample
Average values

TABLE III
LEVELS OF THE CHL A CONCENTRATION AND REFLECTANCE IN BAND 2 (R2). RÍO TERCERO DAM.

Sampling stations	1	2	3	4	5	6	7
Chl a (µg/l)	31	14	9	5	7	4	6
R2	70.046	65.495	64.157	63.086	63.622	62.818	67.747

The studies integrating sensors, GIS and Landsat 5TM images to determine spatial variability of chlorophyll-a showed a higher concentration at the affluent during the spring time (Table III).

For Piedras Moras reservoir, the application of spatial interpolation techniques -kriging- showed that dispersion of total nitrogen was different depending on the season. Total phosphorous at spring showed its higher levels at Soconcho River and Balneario stations [8]. The dominating species in summer were *Microcystis aeruginosa*, *Spirulina platensis* and several genera belonging to the

Bacillariophyceae, with concentrations of 83.8, 149.4 and 15 cells/25 µ l respectively.

Maximal levels of chlorophyll a were observed in spring at those stations corresponding to affluent and recreational areas.

The areas showing high concentration of chlorophyll a are the areas which are receiving untreated sewage, nutrient and pollutant load. In Rio Tercero dam, the chlorophyll a was highly correlated with transformed spectral features of the Landsat TM data, particulary TM2 y TM4 (Fig. 1).

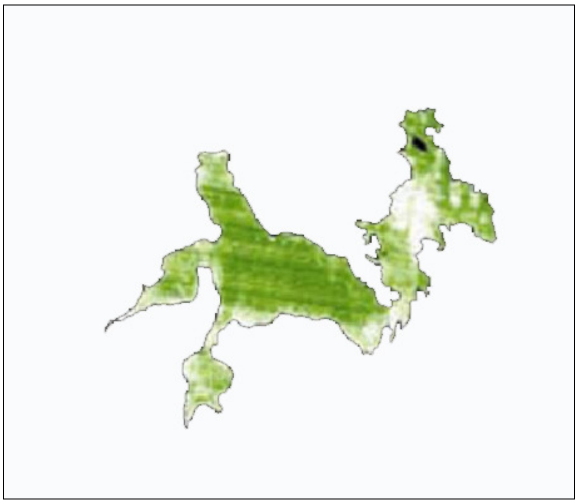

Figure 1. Chlorophyll a distribution in Rio Tercero reservoir. Landsat 5TM. CONAE. 2005.

VII. RISK FOR HEALTH AND ENVIRONMENT

According to our results, the risk for bloom production is high during the whole year except during the fall [9]. Río Tercero and Piedras Moras reservoirs presented a low risk of toxins.

VIII. CONCLUSIONS

The state of the studied dams is within the range established in the guidelines proposed by actual legislation. Risk of blooming is high all over the year, diminishing during fall season. Being Piedras Moras the last reservoir in a row of several ones, its situations is advantageous because the other reservoirs retain phosphates and some other nutrients. These preliminary results demonstrate the potential of combining usage of TM data and geoestatistical modeling for probabilistic evaluation of environmental topics.

Because of the importance of these systems, it is necessary not only their monitoring to evaluate and protect these reservoirs but also to establish an integral program of strategies for the prospective management of reservoirs in order to determine risky areas and early warning systems to protect health.

IX. ACKNOWLEDGMENTS

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The Remote Sensing Perspective to Focus Landscape Ecology, Anthropogenic Action and Malaria Disease

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I. Abstract

Rapid growth of human population, unplanned urban housing processes, fast industrialization, population shifting due to better socio-economic conditions and anthropogenic environmental impacts are responsible for perturbations in the ecological systems at global, regional and local scales. Such changes are affecting the climate, causing alteration of its variability patterns thus originating climatic instability that in turn alter the functioning of natural systems. This has also consequences to human health; a good example of that are the metaxenic or vector borne diseases such as dengue, encephalitis, malaria, leishmaniasis and Chagas disease. In this study it is presented the analysis conducted on the impact of human activities and their relation to the malaria persistence in a regional approach by using satellite images and geostatistics models. To achieve that, we analyzed spatial and temporal effects of agriculture and other common local activities in the Sucre State, Venezuela

KEY WORDS: Remote Sensing, Landscape Ecology, Antropogenesis, Malaria Disease, Sucre State, Venezuela

II. Introduction

Climate change currently observed can be ascribed to a number of causes such as rapid human population growth, urban uncontrolled processes of regional industrialization, forced human populations displacement looking for better living conditions and anthropogenic actions environmental impact with the subsequent alteration of ecological systems.

These changes affects not only climate but are also causing a permanent alteration of its variability patterns. Such variability directly affects natural systems and thus the ecological ones (Delgado *et al.* 2004).

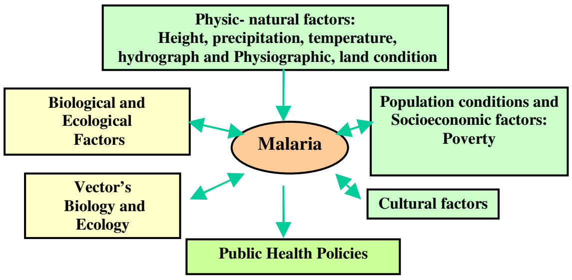

Figure 1. Schematic model of malaria system.

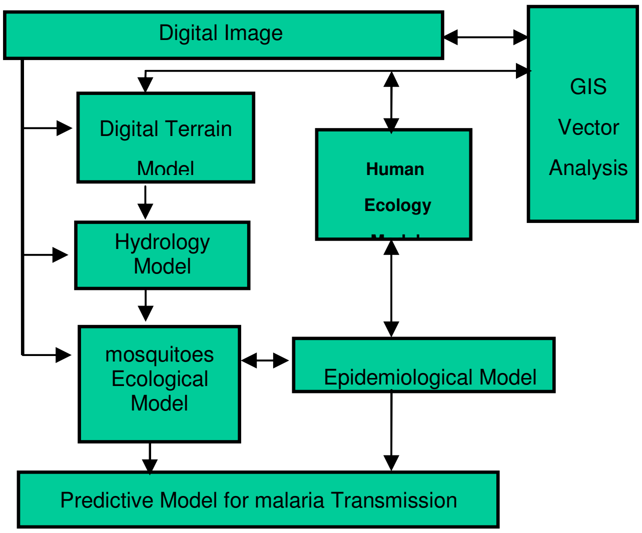

Figure 2. Conceptual Model. Modified from Wood *et al.* (1989)

III. Methods

The State of Sucre has an extension of 11.800 km2 and is located at the Northeaster of Venezuela between the 10°13'10" and 10°44'10"N and the 61°50'44" and 64°30'00"W. In the figure it is marked the Paria Peninsula and Its South slope between the parallels 10°27´00´´ and 10° 42´31´´N and meridians 62°32´00´´ and 63°11´00´´ W.

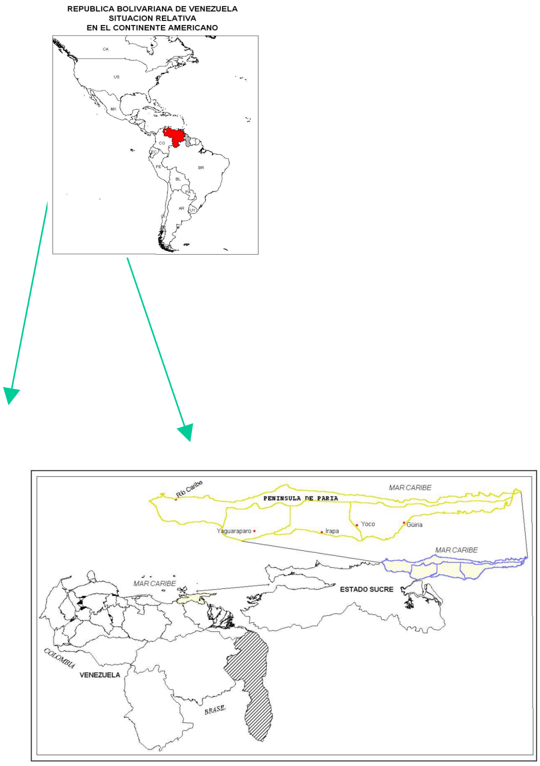

Figure 3. Relative Position of the studied area

It have been used several socioeconomic data derived from the Socioeconomic Indexes from INE (Instituto Nacional De Estadistica E Informatica; Venezuela) and INE-PNUD (2001, 1999): total population, urban and rural populations, urban development level, population growth rate, employment expressed as a fraction for main economic activities and employment opportunity among others.

Moreover, we have used data derived from the Digital Elevation Model generated upon level lines at the scale 1:100.000 and data derived from the Spatial Model of Malaria Regional Incidence years 1990 and 1999 (Delgado *et al*. 2001).

Digital Image processing: LandSat TM5-153. Dec 1990 and LandSat TM 7+ 153. Sept. 1999. Band combination 4,5,3 to quickly detect land use.
Fieldwork: *Anopheles aquasalis* breeding sites survey verified on the mentioned images locations.

IV. Results

The spatial relation derived from the Model of Malaria Incidence 1990 and the Digital Terrain Model is expressed in terms of height and slope level. The analysis shows that main foci of malaria incidence are assigned to localities with the lowest height and slope condition. (Fig. 4.)

In Figure 5 it is visible the high heterogeneity of the plane zones with regards to vegetal cover diversity, natural patterns and anthropogenic modifications.

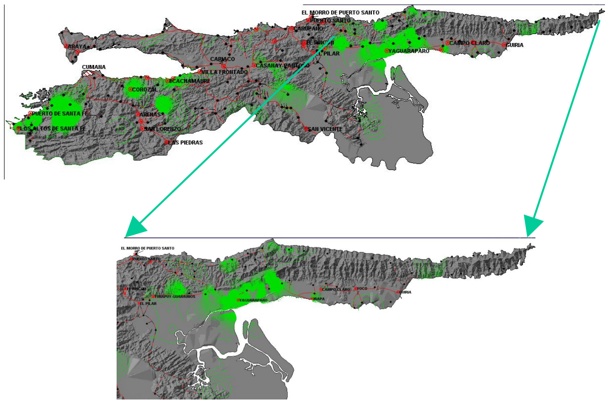

Figure 4. Terrain Model derived from the Topographic Lines at the scale of 1:100.000

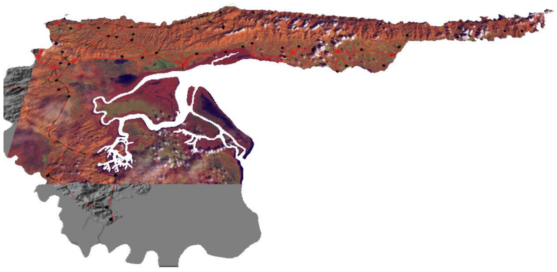

Figure 5. Combination of the image TM5-153- 1990. 4,5,3, bands and Digital Terrain Model.

The figure 6 shows how a more recent image and the inclusion of socioeconomic indexes, coming from INE, allows classification of changes as high, medium and low impact of man activities.

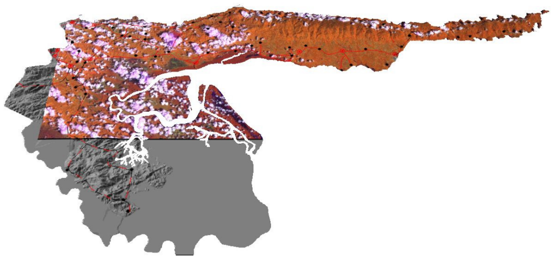

Figure 6. Image combination of TM 7+ 153 1999. 4,5,3 bands and the Digital Terrain Model.

Analysis of socioeconomic index data, and particularly those derived from employment and agricultural activities, reveals that Paria region presents the higher values

Other important indexes, like rural population and low socioeconomic potential (INE, 1999), highlight that only primary activities with very low technological potential and low productivity levels are associated to this region.

Spatial analysis conducted on malaria disease incidences during the year 1990 (on top of the TM5 153 image, Figure 10) shows a strong correlation between sites with major malaria foci, location at the low land zones with no significant slopes and high agricultural activity. A similar response was observed when the same process was conducted on image TM7+ 153 corresponding to the year 1999 (Figure 11), where is observed the increase of the number of malaria foci.

When results coming from spatial analysis were combined with the information regarding land uses and the degree of anthropogenic interventions in land, the correlation is again observed and consistent with data from other authors. Moreover, the correlation was definitively established trough the statistical analysis when Principal Component and Hierarchical Analysis were applied to the data collected. (See figures 7, 8, 9).

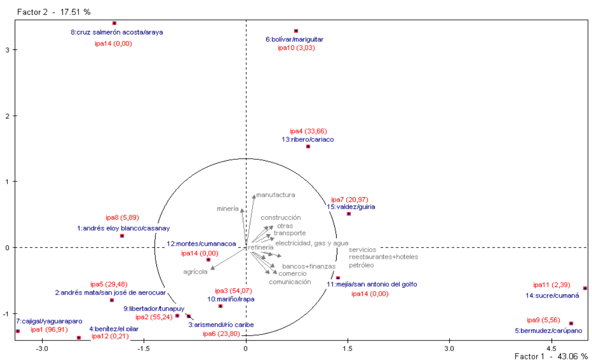

Figure 7. State of Sucre 1999- Main components analysis based on Ipa (Annual Parasitological Index)

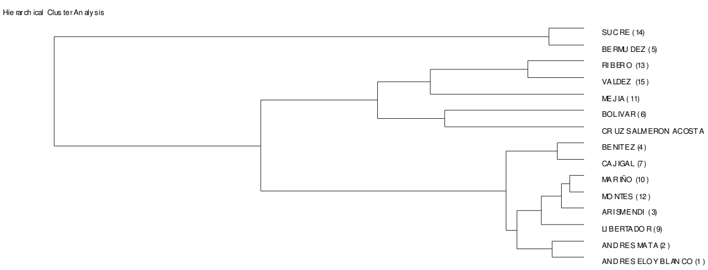

Figure 8. State of Sucre 1999-Hierarchical Cluster Analysis

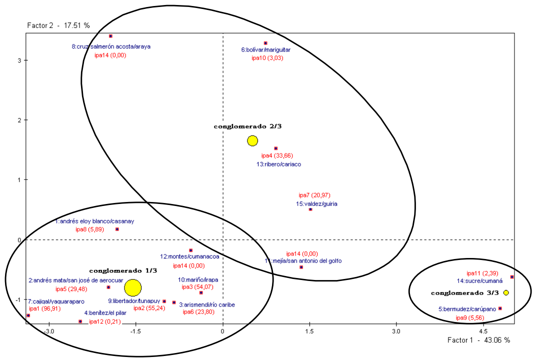

Figure 9. State of Sucre 1999- Hierarchical Diagram

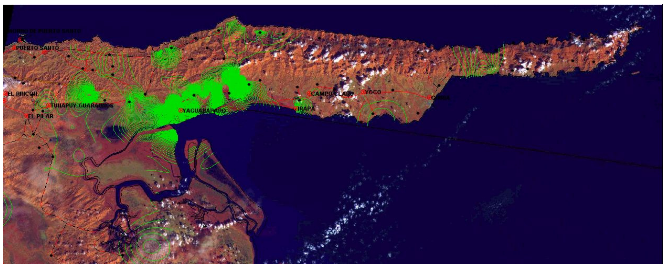

Figure 10. Image 153 TM5, band combination 4,5,3 and The Malaria Spatial Incidence Model 1990

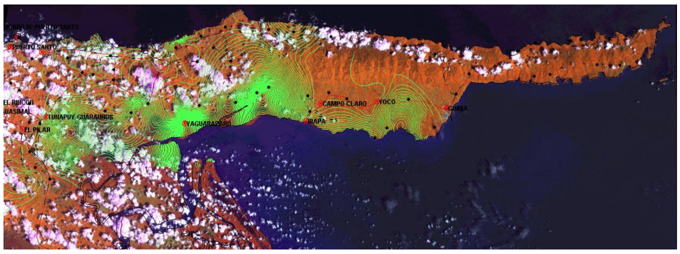

Figure 11. Image 153 TM7+, band combination 4,5,3 and the Malaria Spatial Incidence Model 1999

Lower land areas are strongly impacted and fragmented (Delgado *et al.* 2003a, 2003b, 2003c) and are also the most depressed from the socioeconomic point of view. Because agriculture is the predominant activity in these areas, it is considered that it constitutes one of the major causes favouring the persistence of malaria (Kitron and Spielman, 1998, Gunawardena *et al.* 1998, Keating *et al.* 2003, Klinkerberg *et al.* 2004):

V. CONCLUSIONS

Ecological and socioeconomic variables are tightly related. Both of them must be considered together to develop valid models reproducing dynamic of metaxenic diseases.

From this perspective, malaria represents a nested subsystem within the ecological system modified by anthropogenic actions due to the rural regime existing in the region. Changes in the system, due to low technological input in the agriculture activity and man-made modifications on the system, have favoured the vector persistence and the colonization of new places by the mosquito vector of malaria.

Spatial heterogeneity represent a key variable to be considered in developing and applying public health control plans and policies. Those strategies should consider local features, like agricultural activity and changes in land use, to make them really efficient.

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GIS/GPS for Operational Strategies In The National Program for Chagas Disease Control, Paraguay

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I. Abstract

The Departments of Cordillera and Paraguarí (Paraguay, South America), endemic for Chagas disease, were sprayed in 1999-2000 with two initial attack cycles with insecticides covering all infested localities. The concept of vector elimination is tightly correlated to the finding of the insect; for that reason, an entomological surveillance system was implemented right from the start of the operations. Community participation in surveillance activities was crucial to guarantee the sustainability of the activities. In order to improve epidemiological surveillance in these historically endemic areas, a strategy using GIS/GPS was implemented. Localities that frequently presented *Triatoma infestans* infestation in the domiciliary environment were sprayed with insecticide after GIS/GPS helped us to discover and visualize new distribution patterns and relationships at local level that would have otherwise remained unnoticed. Infested houses identified during surveillance presented with an aggregated pattern in focalized areas. For a better management of the fieldwork and for the detection and elimination of *T. infestans* foci, thus reducing the opportunities for new infestations, GIS technology can support vector control and surveillance.

This study was supported by UNDP/World Bank/WHO Special Programme for Research and Training in Tropical Diseases (TDR), and the Government of Canada through the Canadian International Development Agency (CIDA) within the project “Prevention and Control of Priority Communicable Diseases in South America”.

KEY WORDS: Trypanosoma cruzi, Triatoma infestans, Global Positioning System, Chagas´disease.

II. Introduction

In July 1991, the Ministers of Health of Argentina, Bolivia, Brazil, Chile, Paraguay and Uruguay decided to implement a strategy aimed at the elimination of Chagas disease by interruption of the vector transmission of the disease and the systematic screening of blood donors. One of the objectives included the elimination of *T. infestans* from both dwellings and the peri-domiciliary environment in endemic areas. The definition adopted for the elimination of *T. infestans* was the ¨lack of detection of any specimen of *T. infestans* in the intra-domiciles for a minimum period of three years in an area with entomological surveillance established¨.

The World Health Assembly, on 16 May 1998, adopted resolution WHA51.4 in which it expressed its satisfaction with the progress made in the countries of the Southern Cone Initiative in eliminating the transmission of Chagas disease and acknowledging the decision of the Andean and Central American countries to launch similar initiatives.

In 1999, Paraguay strengthened the national vector-control program carrying out regularly control activities in 12 endemic departments. More than 344,000 dwellings at high risk and distributed in 3,653 localities were evaluated. The organization model was as ¨national campaigns¨, and each locality was evaluated with spatial and temporal continuity. The information data obtained at local level was recorded with special care pay to entomological indicators needed for the certification of the elimination of *T. infestans*, the main vector in Paraguay. Surveillance to ensure the early detection of reinfestation was undertaken after the two initial attack cycles with insecticide and was implemented with community participation combined with active search by program staff. Natural community leaders and school children from rural endemic areas played a special role in the entomological surveillance system implemented by the national program since 2002. If reinfestation occurs, the householder must report it to the designated surveillance site so that control measures can be taken. Supervision visits to such sites by program staff, as well as frequent educational meetings with the community, were also performed. In addition, experience showed that, for vector-control activities, vertical programs are highly effective and easy to carried out. However, in the surveillance phase, with low triatomines densities, vertical programs have low sensitivity and are too expensive to be used.

Historically, maps describing the spatial distribution of vectors and diseases have been limited to hand-drawn representations on pre-existing maps. GIS, with new advances in image processing and GPS to geo-reference databases, provides a new and powerful tool to efficiently store, retrieve and interpret entomological databases for epidemiology, ecology and control studies in Chagas disease.

The National Control Program of Chagas Disease incorporated this technology in the year 2003. The entomological data information recorded during operational control and surveillance activities, combined with the spatial model capabilities of geographic information systems, proved to be useful for characterizing and monitoring the spatial and temporal patterns of those villages where infested houses are detected. With this information, a complete picture of the entomological situation is viewed and updated. Using GIS/GPS technology we designed an operational strategy for vector control in the Chaco Region, an hyper-endemic area where very low density of dwellings are present but with high infestation rate. It was possible to make a cost-effective intervention with more efficient and effective resource utilization, such as number of personnel to be involved, time needed and cost of transportation. The map developed using GIS technology, compared with tables and charts, proved to be an extremely effective tool to show our strategy to the community decision makers of Chaco Central. It was possible to visualize and understand our intervention strategy to solve a public health problem in their well-known territory.

These GIS relational databases are being used as a powerful tool in order to monitor the status control of infested areas and to evaluate the impact of control and surveillance effort to eliminate domiciliary *T. infestans*.

In this study, it is evaluated in some localities a new model of intervention for the detection and elimination of cryptic foci of *T. infestans* in order to avoid the opportunities for new infestations.

III. MATERIALS AND METHODS

The geographic position, latitude and longitude information of triatomine- infested dwellings present in Cordillera and Paraguarí departments was recorded with a III Plus GPS receiver manufactured by Garmin (Garmin International, Inc., Olathe, KS). Infested dwellings detected during surveillance activities were visited by a program staff who recorded latitude and longitude with the GPS receiver.

ArcView 3.2, created by the ESRI corporation, was used as GIS software. The entomological information recorded such as year of detection, bug species and stage, localization (inside the house – domiciliated or in the peri-domiciliar), have been used as thematic raster base map for displaying infestation and colonization rates, dispersion index, by villages, districts and departments.

Departmental, districts and villages border boundary data were obtained with high resolution images (Digital Orthophoto Quarter Quadrangles, or DOQQs) for the entire country.

Global Positioning System (GPS) receivers were incorporated to visualize the precise geographical position of infested dwellings detected during surveillance in the villages and districts of both departments, and Geographical Information System (GIS) was used as an analysis tool to map the distribution of these houses and to incorporate data such as colonization, and localization of the bugs (intra or peridomicilliary). We visualized contiguity areas where persistent infestation was observed during the last three years, and selected six areas to conduct special interventions including spraying and active bug search by program staff.

IV. RESULTS AND DISCUSSION

The National Program of Chagas Disease has detected a persistence of domiciliary infestation of *Triatoma infestans* in some localities of the endemic departments Paraguarí and Cordillera. This detection has been possible through the entomological surveillance system implemented in 2002 and based on community participation and active entomological evaluation made by personnel staff of the Ministry of Health (see results on table 1). It is suggested that the persistence is due to the existence of residual domestic foci and in expansion not previously detected because operative failures made by the regional personnel staff of vector control during their interventions in response to a positive notification made by the settlers.

In this study, we intent to understand the situation of reinfestation through the implementation of an integrative and active search in six strategic areas where the persistence of infested houses was showed during the last three years. A spraying with synthetic piretroide of 100% of the houses present in each area was done followed by an active search of triatominos in each house: triatominos leave the hiding places immediately after the application of the insecticide making easy the detection of bugs. Additionally, plastic bags were given to the settler and instructions for possible captures and notification just in case of detecting triatominos in the 24 or 48 following hours.

Considering the pattern obtained with GPS of the *T. infestans*-infested-dwellings, areas between 10 and 30 square kilometers were selected for the integral intervention (insecticide intervention in all infested and neighboring dwellings). Up to date, this type of spraying intervention was executed based on village infestation rate, and not observed as ¨special infested areas¨. Villages have been mainly focally sprayed (infested dwellings and those present at 200 meters of distance) and occasionally 1 or 2 villages per year was 100% sprayed because historically represented a risk with an accumulation of infestation rate over 5%.

TABLE 1

ENTOMOLOGICAL SURVEILLANCE OF CHAGAS DISEASE WITH COMMUNITY PARTICIPATION

Infested houses notified during surveillance by natural community leaders, householders and school children

	NUMBER OF INFESTED HOUSES							
	CORDILLERA DEPARTMENT				PARAGUARI DEPARTMENT			
YEAR	Natural Leaders	School Children	Householders	TOTAL	Natural Leaders	School Children	Householders	TOTAL
2001					5	57	47	109
2002					24	104	84	212
2003	26	5	2	33	30	18	89	137
2004	12	68		80	23	115	32	170
2005	18	10	5	33	31	41	39	111
TOTAL	56	83	7	146	113	335	291	739

YEAR **1999.** Baseline. Integral Vector Conrol in Paraguarí Dpt.- 1.325 infested houses/ 53.575 total houses present.
YEAR **2000.** Baseline. Integral Vector Control in Cordillera Dpt.- 506 infested houses/41.308 total houses present.

Figures 1 and 2 show the six areas selected for this study with the distribution of infested dwellings notified during surveillance by community leaders, householders and school children in the last three years.

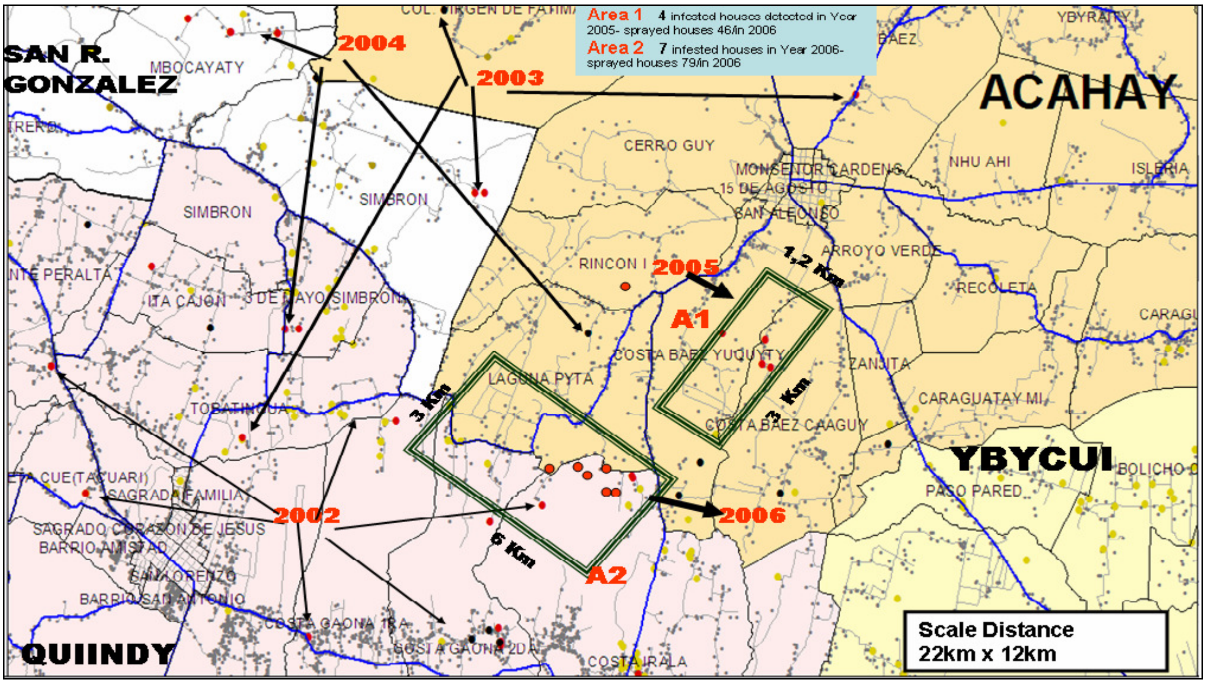

Figure 1. GIS/GPS in Paraguari Department. The strategically selected areas were labelled with squares. These results were obtained in two districts: Area1, that involves just the district of Acahay and two localities (Costa Baez Yuquyty and Costa Baez Caaguy); in this area the intervention involved 46 houses. One house was notify by school children in year 2006, and 3 more houses were notify as infested in year 2005 (already sprayed in 2005). Area 2, involve two districts, Acahay and Quiindy, and four localities (Costa Gaona, Costa Irala, Costa Baez Yuquyty and Laguna Pyta); in this area the intervention involved 79 houses. Seven houses were notify by school children in year 2006, but after spraying just one of them was infested

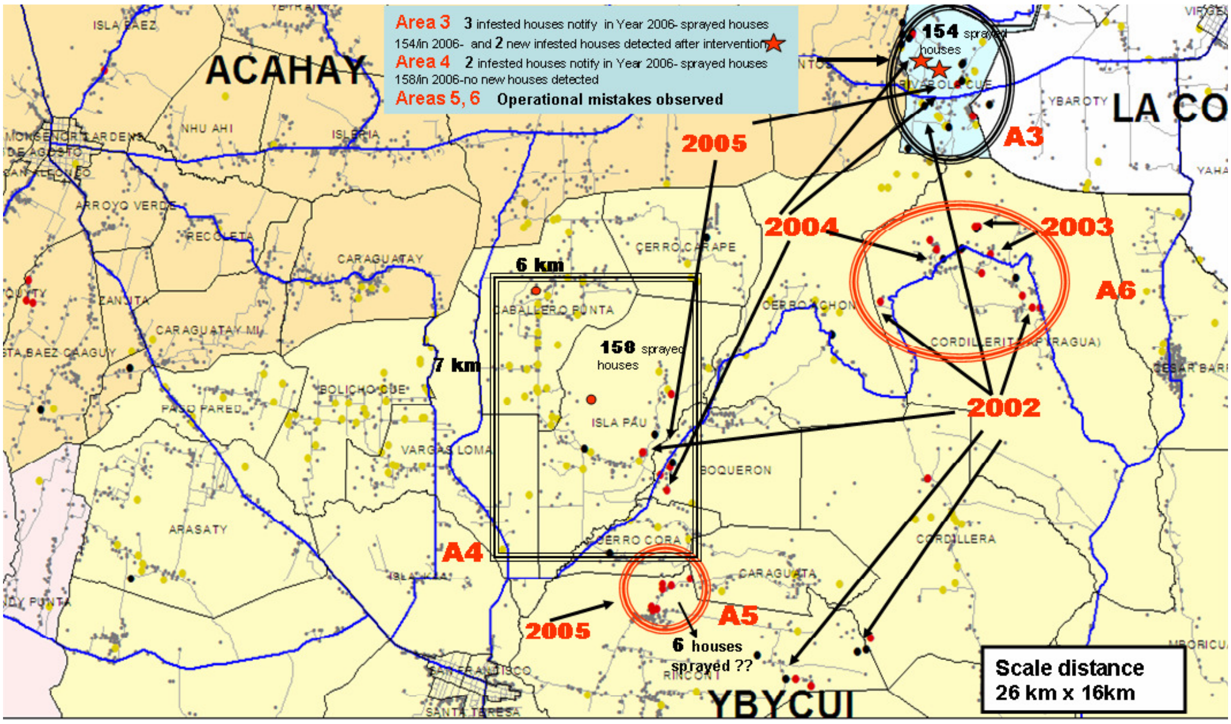

Figure 2. GIS/GPS in Paraguari Department. The strategically selected areas were labelled with black squares and red circles. These results were obtained in two Districts, Ybycui and Ybytymi: Area 3, represents the locality of Rivarola cue, with 154 houses 100% sprayed, infestation have been notify by the community during years 2002, 2004 and 2005. Focal interventions were performed each year, because just adult cases were detected and no triatomines were detected after spraying. Out of the three houses detected by school children in year 2006, just one of them was confirmed to be infested with nymphs. Surprisingly, one infested house located 500 meters from the notified house, was detected by the personal staff, this one would not be notice with our Focal system of intervention, and it could probably be the foci of *T. infestans* dispersion in the community during these years considering the high colonization and triatomines density detected intradomiciliary (house conditions was very poor and the construction was very old). Areas 4, 5 and 6 were located in Ybycui district. Areas 3 and 4 (black labelled) were correctly sprayed and evaluated by personal staff, areas 5 and 6 were not performed correctly and operational mistakes were detected with GIS/GPS. In Area 4, that involves just the district of Ybycui and four localities (Caballero Punta, Isla Pau, Boquerón y Cerro Corá), the intervention involved 158 houses. Two houses were notify by school children in year 2006, and 5 more houses were notify as infested in the year 2002, 2004 and 2005 (they were focally sprayed in those years). No more infested houses were detected after this intervention, just the one notify by one school children in 2006 resulted positive for *T. infestans.* Area 5 shows an operational failure performed by personal staff: it was programmed to spray all houses present in the circle labelled in red (more than 25 houses) but just 6 houses were sprayed. This type of mistakes could leave foci of *T. infestans* in not treated houses. Area 6, this is a risk area that was left, and considering the conglomerated infested houses detected from 2002 to 2005, houses present in this area could spread the infestation in the future. Represented with Dots of different colors are GPS labelled houses RED and BLACK: *T. infestans*-infested houses detected during surveillance from 2002 to 2006 with colonies and adults, respectively. YELLOW: *T. infestans*-infested houses detected during Vector Control activities in 1999. GREY: small dots representing total houses present in the localities. Numbers in Red represent the year of the detection, and arrows show the exact place of the infested house detected.

On the light of the different epidemiological situations and organizational structures of the control programs in each country, it was agreed that countries should adopt common concepts, indicators, and operational standards. The definition adopted for the elimination of *T. infestans* was the ¨lack of detection of any specimen of *T. infestans* in the intradomiciles for a minimum period of three years in an area with entomological surveillance established and operative using the research techniques available¨.

GIS/GPS helped us to discover and visualize new distribution patterns and relationships at local level that would have otherwise remained unnoticed. With all this information, it is possible to design a strategic operational field work with reduced cost of intervention thus maximizing the potential and outcomes of available control resources (human, financial and technical).

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AREA 4

SPACE TECHNOLOGY AND INFECTIOUS DISEASES

There is mounting evidence that some environmental and climatic factors are involved in triggering infectious disease outbreaks: for example, increased water temperature favours multiplication of microbial agents, extreme rainfall causes excessive runoff and washing of material of fecal origin into potable water and extreme weather events can impair local sewage systems and cause contamination of water systems. The possibility of monitoring the environment and climate parameters and changes from the space offers the opportunity of predicting and thus preventing those infectious diseases in some way linked to the environment namely water-, vector and air-borne diseases, the so called “climate sensitive” diseases.

In this area are presented a number of projects dealing with the use of satellite to the monitoring of the environment in order to predict the emergence and evolution of waterborne diseases (vibrios infections and algal blooms in Chile) and vector borne diseases such as malaria developing in highland areas of Bolivia because the increase of temperature and dengue influenced by rainfalls in Colombia. Moreover, it is presented the experience of two scientific entities, the French Space Agency (CNES) which is applying spatial technology to different areas of Telemedicine including Tele-epidemiology and the Instituto de Altos Estudios Espaciales “Mario Gulich” from Argentina which has developed in Argentina specific experiences of Landscape epidemiology applied to the study of vector and rodent-borne diseases.

Satellites and Health Early Warning for Environmental Risks

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I. Summary

It has been definitively demonstrated that some important health outcomes are tightly associated with environment, weather, and/or climate.

Among these are temperature-related morbidity and mortality, health effects of extreme weather events (storms, volcanoes, earthquakes, floods, droughts), air-pollution-related health effects, water- and food-borne diseases, and vector- and rodent-borne diseases.

In order to predict and prevent these health threats, monitoring the environment and climate parameters and changes from the space is becoming mandatory.

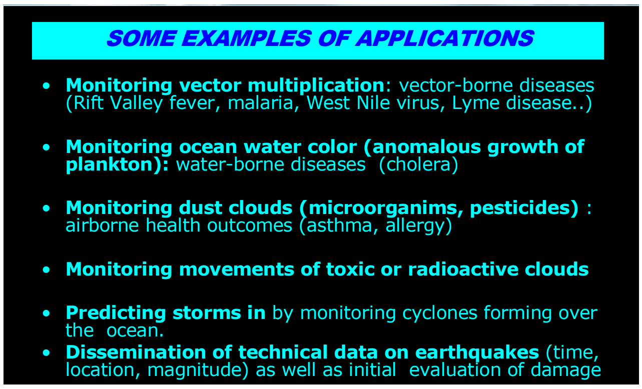
II. Key Advantages in Using Satellites in EWS

1.- Large amount of data obtained from the **permanent monitoring** of the environment via SAT. Possibility of integrating these data and complementary data in predictive models to study communicable disease transmission and extreme meteorological event patterns and trends

2.- Possibility of **predicting** outbreaks/natural disasters in **specific areas within times compatible** with the preparation of an adequate response. Other EWS can detect "current" emergencies to prevent undesiderable consequences and diffusion but can hardly predict them.

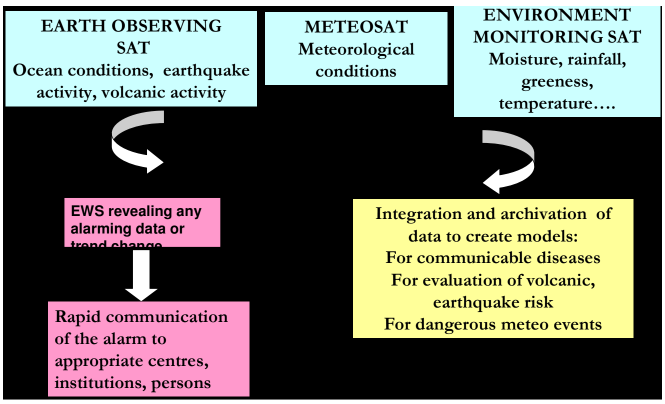
3.- Development of a **growing database** which will provide future generations with **increasingly accurate predictability**

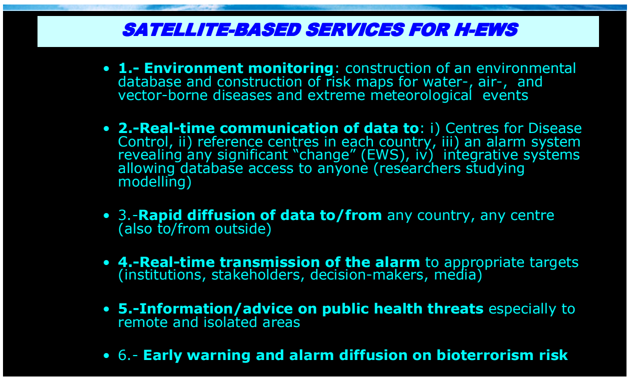
4.- Possibility of **large coverage, including isolated, remote areas** which would otherwise not be monitored and allowing equal access.

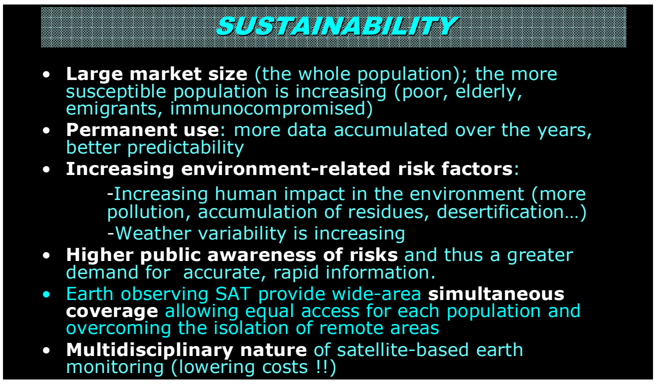


The high amount of data provided by satellites can be used to set up H-EWSs capable of revealing any alarming data or changing trends and of rapidly communicating the alarm for adequate targets (centres, institutions, stakeholders). Satellite technologies can also be used in H-EWS to centralise, make accessible and deliver databases to public health bodies, decision makers, and health information centres.

Moreover, data obtained by satellites can be integrated with other data (epidemiological, veterinarian, clinical) to feed mathematical predictive models in order to forecasting risks of infectious disease outbreaks







III. CONCLUSIONS

The **use of satellites is mandatory** to create an Early Warning System capable of predicting communicable disease diffusion patterns, risk of disease outbreaks and extreme meteorological event related health threats on the basis of an enlarging database constructed by continuously monitoring the environment.

Moreover, the **transmission, in real time, of alarming data via satellite** would allow prediction to occur in times compatible with the setup of adequate protective measures for the safeguard of the citizens' health.

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Satellite-based Early Warning Systems to Predict and Alert on the Risk of Waterborne Disease Outbreak

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I. SUMMARY

A great deal of information on environmental and climatic factors involved in triggering infectious disease outbreaks has been obtained in studying auchthoctonous microorganisms which have their natural habitat in marine/freshwaters such as *Vibrio cholera*. *Vibrios* can adhere to algae and zooplankton and in this way they can survive and spread in the ocean. The increase in sea surface temperature (SST) and other environmental and climatic changes favour an anomalous multiplication of plankton and consequently of bacteria adhered: concentrated vibrios can more easily infect humans. Recently two large *Vibrio parahaemolyticus* epidemic have been described in the South of Chile causing a number of severe cases of disease and important economical consequences. By using information provided by satellites it has been possible to establish a relationship between sea surface temperature and algal anomalous proliferation in the Chilean marine environment. This relationship would be the basis to set up an satellite-based Early Warning System (EWS) to predict increasing numbers of plankton-adhered vibrios and prevent the risk of consequent disease outbreaks.

II. INTRODUCTION

Waterborne (WB) and other infectious diseases represent currently an important threat for human health because of the emergence of new microbial species and strains, the changes in the immunological state of the population (immunocompromissed, aged people) and the pressures caused by increasing population and climatic changes among other reasons. During last years it has been observed a decrease in the microbiological quality of water and an increase in waterborne disease (WBD) outbreaks worldwide.

There is mounting evidence that some environmental and climatic factors are involved in triggering infectious disease outbreaks: for example, increased water temperature favours multiplication of microbial agents, extreme rainfall causes excessive runoff and washing of material of fecal origin into potable water and extreme weather events can impair local sewage systems and cause contamination of water systems. On the basis of these data some infectious diseases are currently considered as "climate sensitive" including also waterborne diseases (cholera, salmonellosis)[1].

A great deal of information on WB pathogens and environmental factors derives from studies on auchthoctonous microorganisms which have their natural habitat in marine/freshwaters such as *Vibrio cholera*. *Vibrios* can adhere to algae and zooplankton and in this way they can survive and spread in the ocean. The increase in sea surface temperature (SST) and other environmental and climatic changes favour an anomalous multiplication of plankton and consequently of bacteria adhered: concentrated vibrios can more easily infect humans. For this reason adhesion of bacteria to plankton represent a survival strategy allowing *Vibrios* to persist in an adverse environment like marine waters[2].

With a changing climate, environmental conditions affect both the overall abundance and, potentially, the serogroup of *V. cholerae*. Moreover, the geographic range of *V. cholerae*, *V. parahaemolyticus* and *V. vulnificus* may also change (changes in salinity for example) resulting in increased exposure and risk of infection for humans. Also changes in plankton population and other hosts (bivalve shellfish, terrestial and aquatic animals) would alter the ecology of these pathogens.

To predict and prevent waterborne disease outbreaks it could be very useful to rely in an Early Warning System (EWS) revealing any alarming data or trend change in the climatic/environmental factors influencing the presence and persistence of WB pathogens. Usually, EWS are based on telephonic and telematic communication networks and on epidemiologic data but the application of space technologies to EWS is currently object of increasing consideration: only satellite-based EWS could predict infectious disease outbreaks within times compatible with the preparation of an adequate response[3]. Moreover, the permanent monitoring of the environmental factors by earth observing and meteorological satellites would facilitate the construction of growing databases which, integrated with clinical and epidemiological data, could be useful in setting up more efficient EWS and in creating predictive models: the development of a growing database will provide future generations with increasingly accurate predictability. Finally, satellites provide large coverage, including isolated, remote areas, which would otherwise not be monitored, and allow equal access to any population[3].

III. OBJECTIVES

To evaluate the possibility of developing an EWS based on the use of satellite-provided data regarding phytoplankton blooms and specific ocean parameters in order to predict and prevent the risk of environment-related infectious diseases and economical losses in aquaculture of shellfish and fish exploitation areas.

IV. MATERIALS AND METHODS

Satellite products derived primarily from MERIS and AATSR instruments aboard the ESA ENVISAT spacecraft has been used together with *in-situ* observations. Data from the MODIS instrument aboard NASA TERRA and AQUA satellites have been also integrated. ENVISAT data has been analysed using the software BEAM developed by ESA and MODIS data has been processed using SeaDAS distributed by NASA. Satellite data were obtained in Level 1 and level 2. Isolation from water and faecal samples and identification of *Vibrio parahaemolyticus* was performed using standard methods[4]. Epidemiological data on the number of persons affected by the disease (infection by *V. parahaemolyticus* was suspected if patients had watery diarrhoea and had eaten raw or undercooked seafood, especially shellfish) were obtained from Ministry of Health.

V. RESULTS

Several satellite oceanography applications have been carried out in the southern region of Chile[5] and among these, coastal monitoring activities related to human poisoning due to consumption of seafood affected by harmful algae or bacteria as *Vibrio parahaemolyticus*[6].

During the year 2002, an outbreak of the species *Alexandrium catenella*, host of Paralytic Shellfish Poisoning (PSP), has been detected in south of Chile and was responsible of 73 human intoxication cases and two deaths. The outbreak affected that area of the country where shellfish exploitation represent the 60% of the total amount destined to international markets. The region of 43ºS was closed for shellfish extraction between the years 2002 and 2004.

On the basis of previously proposed links between environmental parameters, quantity of phytoplankton, concentration of zooplankton-adhered vibrios and risk for human health[2], data from the SeaWiFS instrument, on board SeaStar, and Near Real Time data from ENVISAT, Terra and Aqua satellites were used to demonstrate the feasibility of using ocean colour remote sensing to follow microalgae bloom. These events could represent a health risk for the population in that algae carried any harmful toxin. The algae bloom can also be harmful for the aquaculture industry as they produced suffocation of fishes in the cages or other negative effects.

Since 2003, some bacterial species have been detected for the first time in waters of the region and one of them was identified as *Vibrio parahaemolyticus*. The isolated strain was responsible for more than 1.500 intoxication human cases during the 2004 austral summer.

It has been demonstrated[2] that increased water temperature and other environmental parameters accelerate the vibrios growth rate and favour their concentration on plankton thus increasing the risk for human health. Using the remote instrument AATSR aboard ENVISAT satellite and ancillary data, main areas for seafood resources at risk for being infected with bacteria were determined helping local health authorities to define areas at high risk of intoxication and avoiding the closure of low-risk areas.

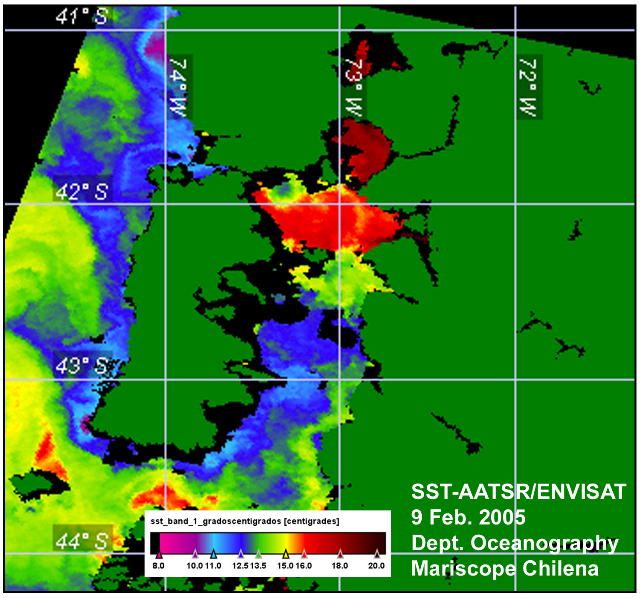

Figure 1. Sea Surface Temperature (SST) from the European Environmental Satellite ENVISAT. The data where obtained through a scientific project of the Earth Observation section of ESA.

During summer of 2005 the preventive actions did not include sanitary barriers, nor restrictions on the shellfish extraction and this led to an countrywide epidemic with more than 10.000 intoxication cases and one human death.

In Figure 2 is presented the temporal evolution of intoxication cases during the *V. parahaemolyticus* outbreak of the summer 2005. As it is shown, using remote sensing it is possible to anticipate up to 6 days detection of the first bacterial disease cases.

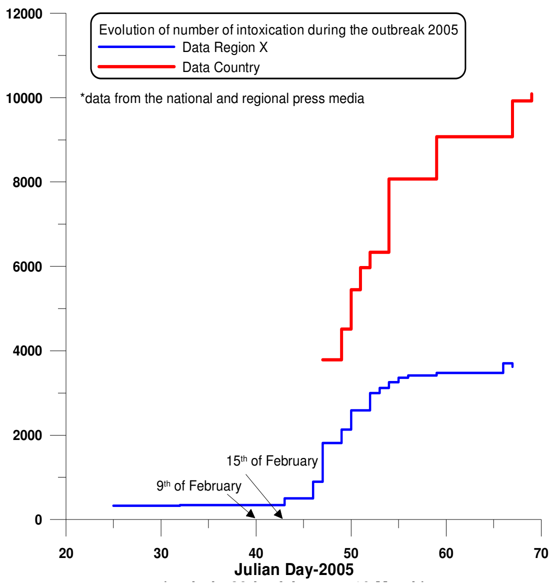

Figure 2. Temporal evolution of intoxication caused by Vibrio parahaemolyticus in Chile during the outbreak of 2005.

VI. CONCLUSIONS

The results presented in this study are part of the first ENVISAT data application in Chile, mainly focused on early warning for prevention of human health risks in an economically interesting area for shellfish exploitation.

Shellfish can concentrated in their bodies, which are sources of food for human use, bacteria or toxins present in waters. The presence of some harmful organisms such as *Vibrio parahaemolyticus* is considered a justified reason to close the extraction during critical periods, as indicated by the European Community in 2001[8]. However, to be able to prevent the total closure exploitation activity in the region and to restrict the areas of risk for human health would avoid unnecessary negative economical repercussions. Extraction prohibition of marine resources implies a considerable economic crisis, such as the one experienced after the summer of 2002, when an algal bloom caused by the toxic species *Alexandrium catenella*, caused 73 cases of human intoxication and obliged the Government of Chile to declare the state of catastrophic area. For this reason the exclusion of risk-free areas is considered of great social impact.

Moreover, satellite data can help to monitor extended areas and to plan the *in situ* measurements.

The setting up of an Early Warning System must rely on biological basis relating environmental/climate factors with persistence and diffusion of bacteria present in waters: only in this way detection of significant modifications of those specific parameters would allow the prediction of increased risks to human health linked to higher concentration of infectious agents in the environment. With an efficient EWS, the exploitation of the shellfish resources could be blocked only where and when increases in SST are detected by remote sensing. Thus, the emergence of algae blooms can be detected (by measuring ocean colour via satellite and ancillary *in situ* data) several weeks before the increase of the level of toxins or bacteria concentration in shellfish and therefore before detection of human intoxication cases[9].

The possibility of using data from satellites would allow to early detect changes in environmental/climatic parameters favoring the development of algae blooms and/or increases in plankton-adhered bacteria in time to carry out mitigation procedures. Moreover, integration of these data with microbial, veterinarian and field data would facilitate preparation of maps of risk areas for the emergence of environment-related diseases.

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Integrated Analysis of Malaria Outbreaks in Tuntunani (Bolivia) at 3800 Metres.

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I. Introduction

The climate change can affect human health in direct and indirect forms, being one of these effects the increase in vector borne disease incidence. An unusual local malaria outbreak (January -May 98) was reported in the Andean highland region at an altitude of 3800 meters. Outbreaks of this type show strong correlations with climate changes and ecosystem modifications.

II. Objective

To evaluate a malaria outbreak in Tuntunani, Andean region of Bolivia, from an integrate perspective.

III. Methodology

Climate change and variability scenarios, comprehensive ecosystem evaluation, searching for habitat modification in highlands (Tuntunani, Mollebamba and Sehuenkera) and use of satellite imagines and geographic information systems were used to conduct an epidemiological integrate assessment (surveys, clinical examination, laboratory tests) of the risk for malaria outbreaks.

IV. Results and Discussion

Since 1991, it has been recorded in highlands of Bolivia a continous increase of temperature as compared to the baseline period 1960 -1990. This environmental modification has caused a number of ecosystem and vector impacts including the development of conditions favouring disease vector growth. It is the first time that a malaria outbreak is detected in a place at so high altitude (3800 meters) considered historically as a cold area with temperatures ranging between 10° and 15 °C. Furthermore, it has to be considered the influence in the ecosystem of the strong ENSO event 97/98, causing an increase in sea surface temperatures (table 1), increased air temperatures and unusually frequent rainfalls confirmed by NDVI index values.

Seasonal classification: Surface Sea Temperatures for South America 1996 -2000

Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
1996	C–	C–	C–	N	N	N	N	N	N	N	N	N
1997	N	N	W–	W–	W	W	W+	W+	W+	W+	W+	W+
1998	W+	W+	W+	W	W	W–	N	C–	C–	C	C	C
1999	C	C+	C+	C+	C	C	C–	C–	C–	C	C	C+
2000	C+	C+	C+	C	C	C–	C–	N	N	C–	C–	C

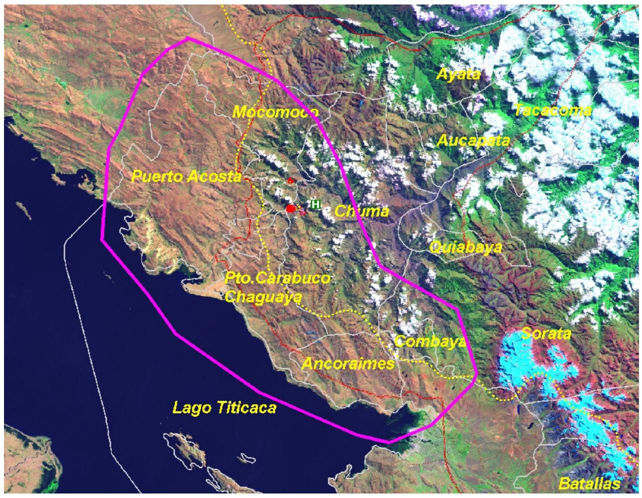

Figure 1. Panoramic view of the studied area LANSAT 5

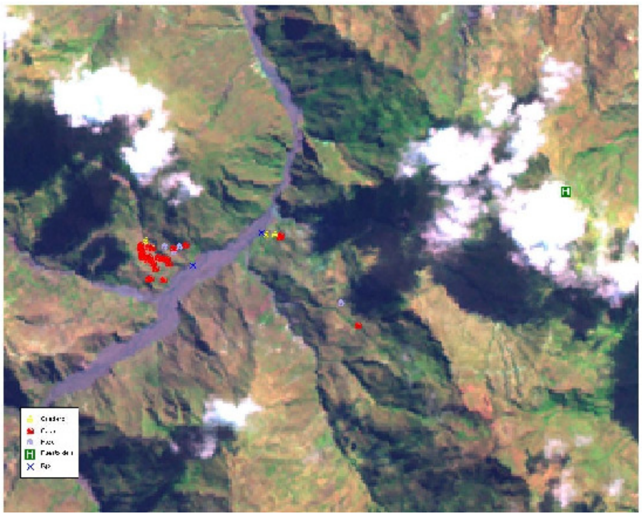

Figure 2. GIS localization of Tuntunani Malaria Cases

V. Conclusions

A local malaria outbreak has been detected in January -May 1998 in Bolivia highlands at an altitude of 3800 meters.

In the same area, it have been detected climate changes causing an evident increase in temperature. This outbreak in a previous malaria-free area has been then correlated to the ENSO event 97/98, unusual increase temperature favouring vegetation and weather conditions considered permissive for vector persistence and development at this high altitude.

Landscape epidemiology would allow the identification of other highland areas with similar environmental conditions favouring the development of the vector and for this reason at risk for increased incidence of vector borne diseases.

KEY WORDS: climate change, malaria in highlands, landscape epidemiology

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Satellite Image applied to Epidemiology, the Experience of the Gulich Institute in Argentina

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I. ABSTRACT

The advances in the quantity and quality of space information and the continuous development of epidemiological problematic have given major impetuses to Landscape Epidemiology. In this frame, since 2001, Argentine Space Agency (CONAE) and National Health Minister (MSN) started working together to develop new tools for epidemiological surveillance, based on Space Information. In this study we present some examples of these activities developed in the Institute "Mario Gulich".

II. INTRODUCTION

Argentine can be define as a "Space Country". That means that Space Information is vital for Argentine socio-economic development. In this context, the National Space Agency (CONAE) is making great efforts to offer space information to all the socioeconomic sectors of our country and to generate human resources capable to use it. An initiative in this direction is the Institute "Mario Gulich" for Space Studies. Conceived as a non-centralized organization, was initially devoted to offer graduate workshops and courses in basic space technology and its applications. The main goal of these activities is the generation of Early Warning Systems on environmental emergencies using space information. In the concept of "environmental" we explicitly include the Applications of Satellite Images to Epidemiology.

The application of space information to health, particularly the so called "Landscape Epidemiology", is a relatively new interdisciplinary approach that involves the characterization of eco-geographical areas where diseases occur.. Landscape Epidemiology can be considered as a part of a second-generation application of remotely sensed data, where the target (the vector or reservoir of a disease) can not be detected directly in satellite images. It is an holistic approach which takes into account the relationships and interactions between different elements of ecosystems under the assumption that the biological dynamics of both host and vector population are affected by landscape elements such as temperature and vegetation [1], [2], [3], [4].

Here, we present some specific experiences of this discipline developed in Argentina and applied to vector and rodent-born diseases. As a first example, we present some results of rodent population dynamics numerical model and Junin virus infection, (etiologic agent of Argentine hemorrhagic fever, in its host, *Calomys musculinus).* In contrast to the usual statistical approach, the model incorporates satellite-derived environmental data in a causal approach. In a second case, we present a study on the geographical distribution of three rodent species with epidemiological relevance (Hantavirus and Argentine Hemorrhagic fever hosts). It is based on historical vegetation and temperature data derived from NOAA satellite imagery series including also precipitation and elevation data. Finally, we show preliminary results on Dengue research, in particular on the temporal evolution modeling of Breteau and Aedes aegypti House Infestation Indexes observed in an endemo-epidemic zone during 1998 – 2003 period.

III. RODENT BORNE DISEASE (CASE A)

Argentine Hemorrhagic Fever (AHF) is a rodent-borne viral infectious disease that occurs in central Argentina humid pampas. The etiologic agent is Junin virus (JUNV), a member of the *Arenaviridae* family. AHF is a severe systemic disease with hemorrhagic and neurological manifestations. The first cases were recognized in Buenos Aires province in the 1950´s, when the disease was limited to an area of 16,000 km^2. The endemo-epidemic region has spread to Córdoba, Santa Fe and La Pampa provinces, covering nowadays an area of 150,000 km^2 . The incidence of AHF varies in geographic areas among seasons and from year to year. JUNV is naturally maintained and spread by its reservoir the dry lands vesper mouse, *Calomys musculinus*. Known reservoir distribution includes central and northwestern Argentina, (an area much larger than endemic area of AHF). JUNV infection is highly focal in *C. musculinus* and varies among localities, seasons and years. The virus maintenance in nature occurs principally by horizontal transmission between adult males. The principal human infection mechanism is by inhalation of infectious aerosolized particles of rodent excreta. Other potential routes of entry include direct contact with mucous membranes or broken skin or ingestion.

This Project is developed in the frame of the agreements between the National Health Minister and CONAE with the objective of building a causal model of population dynamic and viral transmission, using environmental conditions sensed by satellite as input, to estimate disease incidence and simulate different environmental scenarios.

The model assumes the existence of two sub-populations, "X" representing the non-infected rodents and "Y" the infected rodents. Both "X" and "Y", are expressed as a fraction of the ecosystem species carrying capacity. The temporal equation for the non-infected and infected rodents are:

$$\frac{dX}{dt} = \alpha(1-N)X - \beta XY - \frac{X}{\tau}$$

$$\frac{dY}{dt} = \beta XY - \frac{Y}{\tau m}$$

X = Non-infected host population as a fraction of carrying capacity. **Y** = Persistently infected host population as a fraction of carrying capacity. **N** = Total *C. musculinus* population. (tau) = maximum "mean life span". .α (alpha) = potential (per capita) reproductive rate in absence of carrying capacity constrains. (beta) = average number of non-infected hosts that an infected host can infect during its lifetime. The term XY is the infection rate. **m** = accounts for differential mortality rate. Parameters for *C. musculinus* were extracted from our database and from the literature.

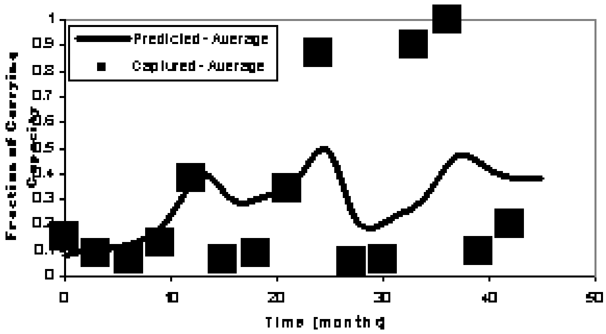

Figure 1. Normalized measured and simulated total population density

As our goal is to develop an alternative method to characterize rodent-borne diseases related parameters, we are interested in identifying those parameters associated with environmental conditions that can be monitored using remote sensors. We selected NDVI derived from the AVHRR instrument, on board the NOAA satellite, as a remotely sensed variable representative of environmental condition. NDVI was chosen because this greenness index integrates environmental information such as temperature and precipitation, that influence host populations biological parameters and, indirectly, measures habitat variables such as the quantity and quality of refuge and food. We assumed a linear dependence of reproductive rate "α" and mean life span " " on NOAA AVHRR NDVI data. So, when NDVI increases (summer) we propose "α" and " " take their maximum values, and when NDVI has lower values (winter) we assume, based on experimental evidence, that birth rate decreases and mortality increases ("α" and " " decrease).

The study area included parts of the Argentinean humid pampas, southern Santa Fe and northern Buenos Aires provinces. This region includes the AHF-endemic area and the large quantity of historical field and epidemiologic data available (last 25 years) gives us a strong cognitive base in order to contrast the model results.

We attempted to evaluate the capability of our model and to describe the temporal and spatial variations of rodent populations monitored at several localities in the study area during 1991-1994. For each locality, the model was run using the corresponding pixel values of NDVI from NOAA decadal imagery during the simulation period. Field data are presented as total relative population densities derived from standardized trap success. Figure 1 presents total population density normalized measured and simulated population density (X+Y+Z) averaged for three localities: Máximo Paz, Alcorta and Pergamino. Figure 2 includes measured and simulated data for each locality. A complete description of this model can be find in [5].

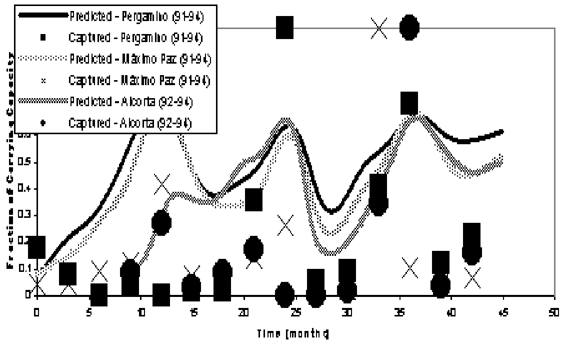

Figure 2. Measured and simulated data for each locality.

IV. Rodent Borne Disease (Case B)

In this second example, we model potential distribution of three zoonoses reservoir rodents: Calomys musculinus, Oligoryzomys flavescens and O. longicaudatus (hosts of Argentinean Hemorragic Fever and Hantavirus pulmonary syndrome). These provide general distribution hypotheses using environmental data of sites where the species were registered. Remote sensing data from climatic and ecological features satellite was used to identify particular environments suitable for these rodents. The three species predictive maps registered high overall accuracy.

The maps obtained (Fig 3) offer several advantages. First, the predictive maps incorporate geographically explicit predictions of potential distribution into the test. (In comparison to other prediction models of species distribution such as GARP, FloraMap, BioMap, etc) Second, the validity of the predictive map can be appreciated when localities where previous records of the studied species, not used as training sites or used as control sites, overlay in the map. In this approach, environmental factor criterion and analytical techniques are explicit and can be easily verified. Hence, we can temporally fit data in more precise distribution maps.

In order to evaluate the potential distribution range of the sigmodontine rodents *C. musculinus, O. flavescens* and *O. longicaudatus,* we used geographic computer databases on spatial distribution of environmental factors including the following data:

Precipitation: A latitude-longitude rasterized grid of a 30-years-monthly mean rainfall having a spatial resolution of 30 min (Leemans and Cramer, 1991; Cramer and Leemans, 2001). IIASA database, Luxemburg, Austria (Available from http://www.daac.ornl.gov)

Vegetation Index: A 1982-1992 time serie of Normalized Difference Vegetation Index (NDVI) from meteorological satellite of National Oceanic and Atmosphere Administration / Advanced Very High Resolution Radiometer (NOAA/AVHRR) with a pixel of 8 x 8 km. NDVI=(Ch2-Ch1)/(Ch2+Ch1), Ch is the channel of AVHRR sensor.

The Land Surface Temperature (LST) of the former temporal series LST= Ch4+3.33(Ch4-Ch5) (Price, 1984), and Digital Elevation Model (DEM): 1 km x 1 km of spatial resolution data from AVHRR sensor, provided by USGS, 1998. Eros Data Center. (Available from http://edcdaac.usgs.gov/gtopo30/gtopo30.asp)

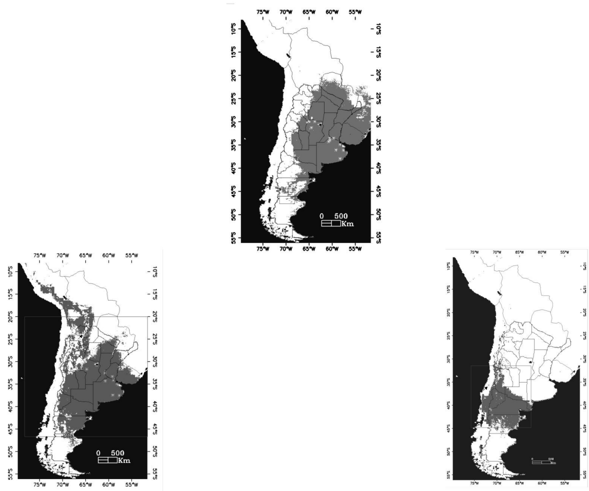

Figure 3. Geographical distribution obtained for C. musculinus, O. flavescens and O. longicaudatus respectively

A complete description of this modelling can be find In [6].

V. Dengue Fever

Dengue fever (DF) and Hemorrhagic Dengue fever (DHF) have become the main problems of health in tropical and subtropical countries where the main vector has expanded, mainly in susceptible populations of urban areas with demographic expansion, affecting populations in extreme poverty. The four known virus serotypes (DEN-1, DEN-2, DEN-3, DEN-4) are transmitted by *Aedes* mosquitos (*aegypti, albopictus, polynesiensis* and *scutelaris*); the circulation of more than one serotype in a place implies the possibility of occurrence of DHF, a severe form of the disease. The DHF mainly affects children and young adults; between the symptoms there are an acute and pronounces sudden fever, haemorrrhagic fenomena, often with hepatomegaly and, in severe cases, signs of circulatory failure. Such patients may develop hypovolaemic shock resulting from plasma leakage called dengue shock syndrome [7]. In Argentina, the recognized vector is *Ae. aegypti*, a cosmopolitan, highly anthropophilic specie that thrives in close proximity to humans and often lives indoors. It is developed in an ample variety of deposits; the females feed themselves by day and have preference by the human blood [8]. In Argentina the Dengue virus reappears in 1997 [9], and at the moment there were Dengue cases in Salta, Jujuy, Formosa, Misiones, Buenos Aires and Cordoba provinces. Nevertheless, Salta was the most affected province (Ministry of Health). Studies made at Salta, Buenos Aires and Cordoba city [10], to consider the abundance of *Ae. aegypti*, indicated a certain situation of dengue outbreak risk.

Approximately 5% of DHF cases are fatal and DF affects about 2.5 million people in more than 100 countries in tropical and subtropical zones, thus, it is considered the most important viral disease transmitted by arthropods [8]. At the moment, vector strategic control is the most reasonable solution to prevent Dengue Fever in countries like Argentina, that present indigenous transmission regions and cases introduction from bordering countries and considering the non-existence of a vaccine or specific treatment available [8]. For that reason, it is necessary to previously develop an efficient early prediction system of vector distribution and abundance.

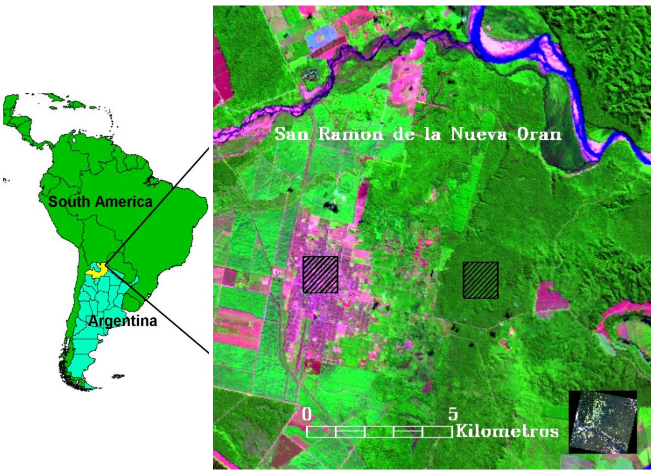

Figure 4. Geographical localization of ORAN

The House index (HI) and Breteau index (BI), also known as Aedic indexes, are entomologic indexes that can be used in studies for the prevention and control of DF and DHF.

$$\textbf{Breteau index} = \frac{\text{Number of infested containers}}{\text{Number of inspected houses}}$$

$$\textbf{House Index} = \frac{\text{Number of infested houses}}{\text{Number of inspected houses}} \times 100$$

The aim of this study is to construct predictive statistical models of temporary variations of observed House (HI) and Breteau (BI) aedic index, of at least 3 years period, for Tartagal and San Ramon de la Nueva Orán cities. Both are located in the base of the Andean mountain region, in Salta Province, at 55 and 45 km from south Bolivian respectively. The figure 4 present the geographic localization of ORAN.

The "multivariate regression" statistical models were based on the following preexisting data: a) Aedic Indexes (HI and BI), b) vector intervention and c) control activities, provided by the National Coordination of Vector Control, National Health Minister, Argentina; d) precipitations; e) Land Surface Temperature (LST) and f) vegetation (NDVI), both derived from Landsat 5 TM and Landsat 7 ETM image series, from two representative subsets (40X40 pixels) of city and native forest (figure 4).

In this way a set of 8 independent variables were obtained: Average and Variance of the temperature for the "city square" and the "forest square", average and variance of the NDVI (for the city and the forest), as well as the precipitation.

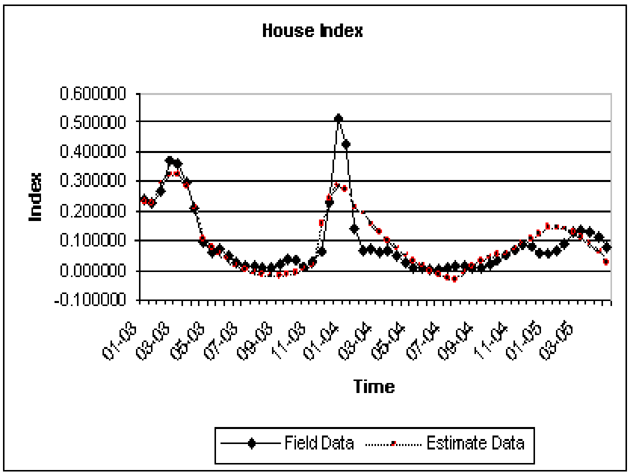

Figure 5. House index measured and modeled

The modeled curves with data of Tartagal have a positive correlation in the range of 0,80 with BI and 0,90 with HI. When using only half of the field data as training set (1998-2000) the results of the model have a prediction for the subsequent year on around 80% for both indexes. For Oran city, the values thrown by the model present a positive correlation in the range of 0,80 for both indexes.

Using the STATISTICA software we have perform a Forward Step-wise multiple regression analysis. For the House index (fig. 5) the correlation was 0.876 and the variables included in the model were: mean city NDVI, forest mean NDVI, forest temperature variance, city temperature variance, forest temperature mean and city temperature mean respectively. Breteau index Correlation was 0.828 (fig.6), and the variables included in the model were: city NDVI mean, forest mean temperature, city mean temperature, city NDVI variance and forest temperature variance. Both indexes p values were statistically significant (value < 0.05 level).

This demonstrates the possibility of using space information in an operative way for the estimation and prediction of epidemic relevance vector indexes.

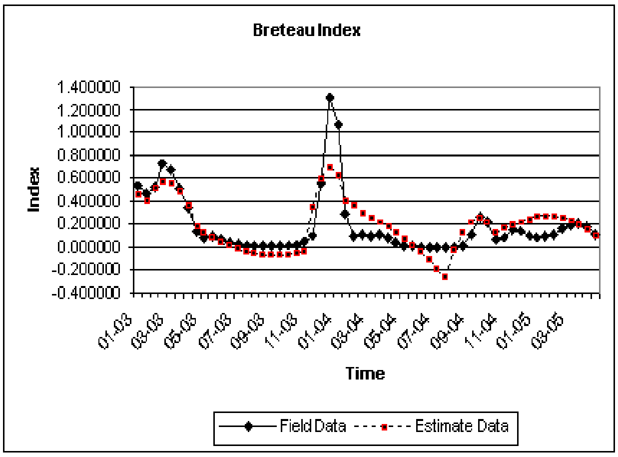

Figure 6. Bretau index measured and modeled

VI. ACKNOWLEDGMENT

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Part of this work is also in the frame of international cooperation Program “MATE”, developed with the French consortium S2E (surveillance Espatiale des Epidemies).

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Relations Between Climate Variability and Dengue and Malaria Cases in Colombia (Elements for its Prognosis)

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I. SUMMARY

The application of statistical models to the study of vector borne diseases has revealed that it exists a lag of time between the emergence of new cases of dengue and malaria and the variations observed in climate indexes. For rainfall, which is the most variable meteorological parameter in this tropical area, the statistically approach has demonstrated that there is a time delay, 8 to 14 week in advance, between the reaching of a rainfall quantity threshold and the emergence of dengue outbreaks and epidemics. For malaria, these lag may be 4 to 5 weeks in hyper-endemic areas. Analyzing climate parameters is then possible to identify rainfall thresholds that act as a trigger of these disease events.

On the basis of these findings, an Early Warning System for dengue and malaria is at present under development in Colombia.

II. INTRODUCTION

Diseases as dengue and malaria have became a serious problem of public health in Colombia. During last years their incidence is increasing as well as dengue is expanding to new geographic areas. As regards dengue for instance, cases have increased from 7,540 cases in 1984 to 83,683 cases in the 2002.

It is well-known the correlation between these diseases and some elements of the global climatic change, specifically the temperature increase. Changes in rainfall or temperature have complex consequences on the pathogen development as well as on a number of vector characteristics such as density, biting-rate and mortality

Moreover, the impact of these climate interactions on transmission also depends on other [climate-independent] components of the dengue and malaria transmission systems, including population density, the proportion of individuals immune to infection, the rate of pathogen introduction, and the creation of vector new habitats as a consequence of human activity. Moreover, there is a number of macro-factors such as human migrations, economic inequalities, and vegetation patterns among others, that may also play a role in increasing the vulnerability of the population to the vector borne infection. For these reasons it is necessary to set up integrate projects to evaluate the potential impact of climate change.

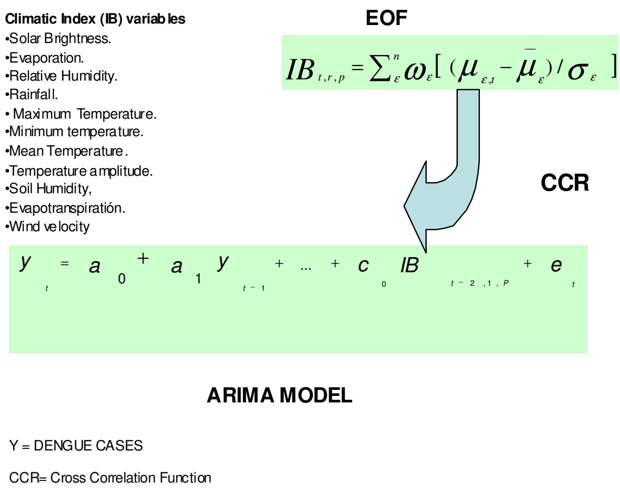
In countries where these diseases are endemic, the temperature apparently has an important influence on the emergence of epidemics, but it is important to also evaluate the influence of other parameters, such as rainfall, which might have an important role. Studies conducted since 2001 suggest an important correlation between dengue and rainfall which determines a noticeable seasonality of this disease. Moreover, the effect of rainfall on malaria outbreaks is less important but also significant.

III. OBJECTIVES

To evaluate the relationships between climate variability and the insurgence of dengue and malaria cases and to develop predictive models as an approach to control these diseases.

IV. MATERIALS AND METHODS

Weekly records of disease cases and values of some meteorological variables at a daily level, rainfall, solar brightness, evaporation, maximum and minimum temperatures, relative humidity and temperature amplitude, were obtained from January 1997 to January 2000.



Graphic 1. Modeling used in dengue and malaria studies

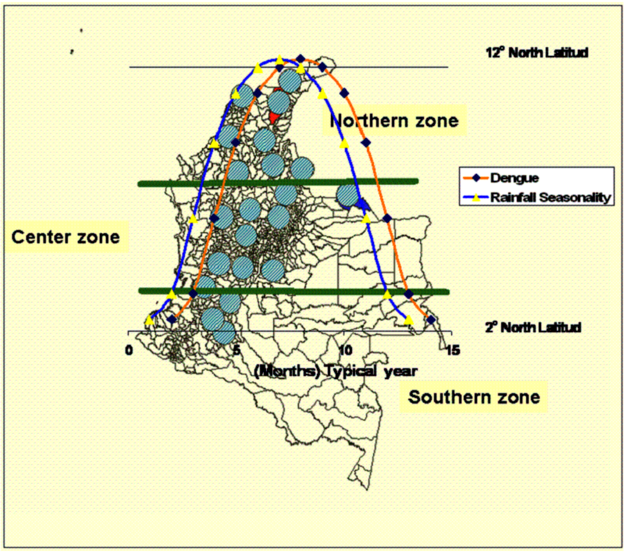
Using these variables, standardized by the robust median method, a characterization of the region's climate was done.

Process of modeling initiates by obtaining the autocorrelation and partial autocorrelation functions, which indicate if average and variance do not change over time, or, on the contrary, whether the series have to be differentiated.

The climatic factor included in the model as an index is obtained by a Principal Components Analysis or Empirical Orthogonal Function (EOF) from the set of meteorological variables. The ACP or EOF, is a very powerful tool for the analysis of the temporal and spatial variations of the analysed fields. The climatic index is a variable that modulates the behavior of the series of disease cases and is also introduced in the model.

V. Results

From the results obtained in this study, it is deduced that increases in rainfall are associated to a greater number of dengue disease cases. If there is an increment of 100% in precipitations, it is possible to observe, several weeks after, the appearance of dengue epidemic periods. . Analyzing climate in several cities in Colombia, it has been demonstrated with this model the appearance of dengue outbreaks between 9 and 14 weeks after the rainfall increased.



Graphic 2. Dengue seasonality in Colombia

The graphic shows how dengue outbreaks follow the rainfall increase by a lag of approximately two months across the national territory and during a standard year. However, there are specific differences among localities and due to intra-annual variability. It is possible to face with these differences by the statistical modeling in real time (See Graph 2)

The fact that rainfall have a faster effect in one city as compared to others seems to be related to the higher temperature, but also can be related with the different strategies of intervention to control the disease.

These findings suggest that the effect of rainfall on the proliferation of mosquitoes breeding sites would be underestimated. The control strategies arein fact insufficient in that they are focused only in intradomiciliary reservoirs and some others located close to the houses, while recently it has been found that indeed the rainfall drains are an important reservoir of *Aedes aegypti*.

The effect of rainfalls on malaria outbreaks in hyper-endemic areas also appears evident 4 to 7 weeks after important increases in the precipitation are observed. In sites where the precipitation does not favour the presence of mosquitoes, the effects appears between 11 and 12 weeks later.

On the basis of the results obtained, it is suggested that this modeling could be the base for an Early Warning System for predicting dengue and malaria outbreaks. An early warning system should consider not only the effect of the climatic threat but also to detect the aspects of the vulnerability to these diseases, over which it is possible to act in a more effective way. For this reason, this kind of model, coupled whit dynamic models, can predict outbreaks efficiently.

IDEAM (Institute of Hydrology, Meteorology an Environmental Studies), has obtained from the World Bank, through the GEF (Global Environmental Fund), resources to finance the project "Adaptation to Global Climate Change on Colombian High Mountain Ecosystems, Caribbean islands, and Human Health". This project will last 5 years from July of 2006.

A multidisciplinary group has been organized, with professionals of the health sector of the National Institute of Health (INS), universities and research institutes.

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Strategy Towards Sustainable Services in Tele-health and Tele-epidemiology

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I. SUMMARY

Since 1999, CNES in the frame of the S2E consortium (Space Survey for Epidemies, gathering CNES, MEDIAS, MEDES, CLS, Institute Pasteur and Ecole Vétérinaire de Lyon) has been working with health professionals to consider how space-based systems could improve health care, notably through telemedicine applications. Potential users have identified two key areas: teleconsultation to ensure good-quality diagnosis for extremely isolated populations, and tele-epidemiology to combat deadly viruses and bacterial diseases.

II. INTRODUCTION

The goal of this paper is to present CNES activities in Health, and the strategy developed by Application and Valorisation Department at CNES in term of technology transfer to ease creation of new services in tele-health and tele-epidemiology. Today, many case studies have proven the value and effectiveness of such systems. Teleconsultation and tele-epidemiology prove that existing resources satellites, medical kits, infrastructures and so forth can be exploited to improve quality of treatment, particularly where environmental conditions are precarious, and achieve significant savings in public health costs. Ground-based data collection and transmission networks supported by satellite imagery can play a vital role in preventing the spread of diseases due to environmental factors. And epidemic monitoring networks can be a first step toward a European health early-warning system, as suggested by the European Commission and voted by the European Parliament.

Various types of satellites can contribute to providing services in different health domains.

- Communication satellites can be used to establish a direct link between isolated sites and central hospital, in order to exchange expertise for a diagnostic and decide of the opportunity to evacuate a person or not. This can lead to sustainable financial gains.

- Data collecting satellites can be used to collect data all over the world, and transmit them to users in near real time.

- Remote sensing satellites for earth observation, oceanographic altimetry, with on board optical or radar sensors, scatterometers, lidars, radiometers, can contribute to environmental and climatical parameters observation.

- Navigation satellites can contribute to geo-localisation.

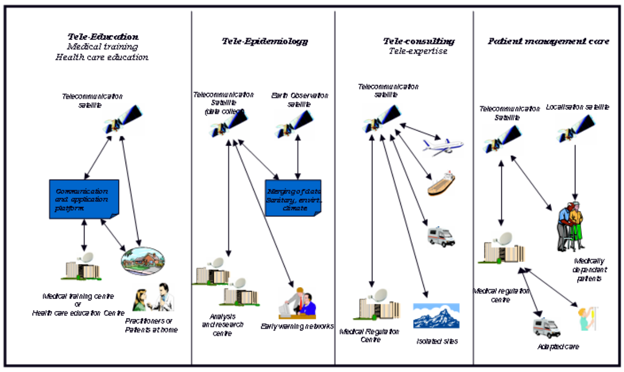

Figure 1. Satellites and health applications

Satellite contribution has to be understood as a tool, in addition to existing ones. They can be operated in complement with terrestrial infrastructures to provide 24/24h services.

III. ORGANISATION AND STRATEGY

A. *CNES organization*

Since its re-organisation in 2003, Application and Valorisation Department is part of the Directorate for Strategy, Programs, Innovation and Foreign Affairs. Its new position in the CNES organisation is the will to strengthen the use of space techniques in new domains, and to address government concern in sustainable development, especially in health.

Actually, Application and Valorisation Department gathers under Dr Guell management:

- 6 persons in charge of Valorisation, econometry, licences and outreach, innovation and start-up supporting,
- 2 persons in charge of Applications development in the domains of Risk management, Tele-epidemiology.
- 1 person incharge of relations with EC.

The persons in charge of valorisation are in relation with their correspondents of the valorisation network of CNES Toulouse technical centre and with the industrial partners.

The persons in charge of applications development are in relation with scientific and industrial partners. All these persons contribute to the outcome of new ideas and projects, as a bidder or as a relay. When an idea gets a good evaluation mark, then CNES supports it on a 50/50 funding approach from its very beginning until its demonstration. After the demonstration phase, users are invited to take over CNES to ensure the complete funding of the operational service. Between the demonstration phase and the operational phase, CNES can contribute to the creation of a service provider to ensure the sustainability of the service.

B. S2E Consortium

Concerning the Applications development in the domain of health, and in tele-epidemiology especially, consortium S2E (Space Survey for Epidemies) gathers several partners from various domains:

- CNES, space techniques and applications development,
- MEDIAS, information system and database, metadata, remote sensing new products dedicated for epidemiology,
- MEDES, information system, data collection and users interface,
- ENVL (Ecole Vétérinaire de Lyon), mathematical modelling,
- Institut Pasteur, virology, molecular bio-analysis, biology, CIBU (Biological Crisis Intervention Unit)

A first agreement was signed in 2001 for a duration of 4 years. Actually, this agreement is being reviewed in terms of partners, contributions and objectives.

S2E consortium has supported several projects, and some are undergoing. Good results have been obtained. The partners are interested in contributing to S2E follow-on. S2E consortium outreach has to be developed to provide scientific and user community with its achievements. A S2E "offer" is being developed, and discussions are undergoing between partners in order to define the most appropriate model for S2E as a moral and economical entity.

C. Strategy and Technology transfer

CNES strategy in technology transfer and in application development can be explained following this scheme:

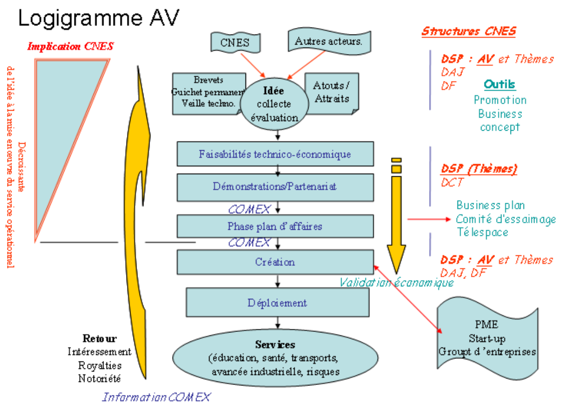

Figure 2. Technology transfert and application development strategy

The main objective is the creation of new services in the domain of health, with CNES financial support from the demonstration project until the business plan of the future service operator firm.

IV. TELE-CONSULTATION

A. Projects supported

A number of space-based telemedicine networks have been set up recently to provide teleconsultations in dermatology, emergencies and tropical medicine. In French Guyana, a pilot experiment was conducted from end 2001 to the spring of 2002, with funding from the Ministry of Health, by Andrée Rosemont hospital in Cayenne and CNES, in close cooperation with the MEDES space clinic. Four health clinics at isolated spots in the Amazon jungle were supplied with telemedicine kits to be able to send imagery and digitized tests via satellite for dermatology, cardiology and tropical medicine. The results were so encouraging that the four sites have been made permanent, and the Ministry of Health and the European Regional Development Fund are providing funding to equip all of the 21 clinics linked to Cayenne hospital with a telemedicine kit.

Looking ahead, other telemedicine projects are in preparation. For example, the Ministry of Health has commissioned a study to deploy telemedicine systems in all of France's overseas territories and dependencies (French Polynesia, New Caledonia, etc.) and those countries for whose health policy it is responsible (Madagascar, Seychelles, Rodrigue, etc.).

Projects concerning medical emergencies in ambulances or during natural and man-made disasters are also being considered as part of ESA's DELTASS initiative (Disaster Emergency Logistic

Telemedicine Advanced Satellite System) and I-DISCARE also funded by ESA.

More recently, responding to French President, Mr.Jacques Chirac to be able to provide support in the early hours of a major catastrophe for crisis management, and under the responsibility of Mrs.Nicole Guedj, CNES, ALCATEL ALENIA SPACE, REMIFOR and French Civil Security, EMERGESAT project aims at developing a transportable device integrating communication tools (satellite communication facilities, GSM, Wifi, …), situation evaluation for risks, water needs and first help. EMERGESATconcept has been presented at Tunis World Submit for Telecommunication and Information in 2006. A prototype is tested and is about to be delivered. An operational version is awaited for early 2007.

B. Service providers created

Major achievements in the domain of tele-consulting are:

- the tele-medecine mobile unit, commercialized by MEDESSAT,

- the creation of the service provider Telemedicine Technologies SA in 2000, a spin off ET ASSIST and Ten Telemed projects supported by EU,

- the creation of another service provider MEDESSAT, a spin-off DELTASS and I-DISCARE projects supported by ESA within the ARTES program. This new firm has been funded by CNES, ALCATEL ALENIA SPACE and MEDES, in the frame of CNES sustainable services strategy.

V. TELE-EPIDEMIOLOGY

Tele-epidemiology consists in studying human and animal epidemics, the spread of which is closely tied to environmental factors.

By combining vegetation index data from SPOT, meteorological data (winds and cloud masses) from Meteosat, and other Earth observation data from Topex/Poseidon and Envisat (wave height, ocean temperature and colour) with clinical data from humans and animals (clinical cases and serum use) and hydrology data (number and distribution of pounds, water levels in rivers and reservoirs), we can construct predictive mathematical models.

A. Projects supported

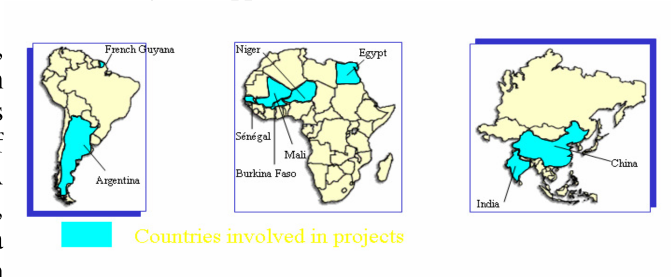

Figure 3. International cooperations

We tested several years a number of such approaches:

- in Senegal, Rift Valley fever epidemics are being monitored using a predictive model based on the rate at which water holes dry out after the rainy season observed by Earth Observation Satellite Data, which affects numbers of virus-carrying eggs; risk maps are defined and used. This epidemiologic data network is operational and is actually operated by the DIREL (Direction de l'Elevage).
- in French Guyana, a tele-epidemiology network was set up to monitor hemorrhagic dengue fever; here again, combining satellite data and epidemiological data is helping to make prevention more effective. The demonstration phase ended in 2004. The operational phase is undergoing.
- as part of the French Ministry of Research's Earth-Space Network, a pilot sentinel network has been deployed in Niger and Burkina-Faso to monitor infectious diseases whose spread is tied to environmental factors. For example, parameters coming from satellite observations such as dust clouds and wind appear to play a crucial role in triggering and spreading meningococcal meningitis. This data collecting network is operational and is actually operated by the CERMES (Centre de Recherche Médicale et Sanitaire).
- in the frame of the cooperation agreement between both Chinese and French space agencies, West Nile Virus, avian influenza and Japanese encephalitis will be monitored through BIBO (Bird Born disease) project stated end 2005.
- lastly, a French consortium is monitoring cholera epidemics around the Mediterranean basin; this project is using mathematical models to assess the risk of a resurgence of the disease, which is linked to numbers of cholera-spreading zooplankton which is quantified by data coming from satellite images of the sea (wave high, currents, colorimetry).

Tele-epidemiology prove that existing resources—satellites, medical kits, infrastructures and so forth—can be exploited to improve quality of treatment, particularly where environmental conditions are precarious, and achieve significant savings in public health costs. Ground-based data collection and transmission networks supported by satellite imagery can play a vital role in preventing the spread of diseases due to environmental factors. And epidemic monitoring networks can be a first step toward a European health early-warning system, as suggested by the European Commission and voted by the European Parliament.

B. Service providers created

As tele-epidemiology is a relatively new domain, first results validated by users have just been obtained. For that reason, it seems too early to have service providers in the short term. But we do expect to reach such an achievement.

VII. CONCLUSION

Since 1999, CNES in the frame of the S2E consortium (Space Survey for Epidemies, gathering CNES, MEDIAS, MEDES, CLS, Institut Pasteur and Ecole Vétérinaire de Lyon) has been working with health professionals to consider how space-based systems could improve health care, notably through telemedicine applications.

Supporting a sustainable services approach, CNES strategy has obtained first tangible results with the creation of new services providers in the domain of tele-consultation.

This approach gives encouraging results in the domain of tele-epidemiology with first products dedicated to professional users in the domain.

These products integrated in an information system for epidemiological data collecting network can be part of an early warning system, providing capable tools for epidemic monitoring as suggested by the European Commission and voted by the European Parliament.

Following its strategy for sustainable services development, CNES has supported the creation of service providers in tele-consultation, and expect such an achievement in tele-epidemiology.

VII. ACKNOWLEDGMENT

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