MAIN ASPECTS OF SOME REMOTE SENSING PROJECTS DEVELOPED AT THE FACULTAD DE CIENCIAS FISICAS Y MATEMATICAS, UNIVERSIDAD DE CHILE.

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ABSTRACT

The objectives, methodology and results of the next projects are summarized in this paper: 1) Study of Antarctic Environmental Conditions and Natural Resources. Spatial, aereal and terrestrial (Satellite Data Collection Systems) observation levels are being used in Antarctic Peninsula; an experimental net of five Data Collection Platforms (Landsat and GOES D.C.S.) has been successfully operated. 2) Study of Geothermal Resources in Los Andes Range. Aereal multispectral photographies and images are being used to study identified geothermal fields (Prospection stage); multispectral and multitemporal Landsat images are being used to identify new areas of geothermal activity, by correlating volcanic structures and zones with abnormal snowmelting conditions. 3) Study of Snow-Water Resources in Los Andes Range. Efforts are being done to stablish correlation models between snowcovered areas (determined through multitemporal/multispectral Landsat images) and the subsequent snowmelt runoff, in the Central Zone of Chile. 4) Study of some Urban Traffic Problems. Conventional B/W aereal photographies are being successfully used to determine the spatial and temporal distribution of the different congestion levels for urban traffic in pilot zones in Santiago.

1. INTRODUCTION

Several projects addressed to solve some important national problems are being developed at the Facultad de Ciencias Físicas y Matemáticas de la Universidad de Chile (Faculty of Physics and Mathematics Sciences, University of Chile), with the partial sponsoring of Servicio de Desarrollo Científico, Universidad de Chile. Remote Sensing Techniques are being used as a valuable auxiliar tool. These projects are being performed with the close participation of several national institutions, specially: Servicio Aerofotogramétrico de la Fuerza Aérea de Chile (Aerphotogrametric Service of Chilean Air Force, SAF); Dirección General de Aguas del Ministerio de Obras Públicas (National Water Survey, DGA); Comité Geotérmico de la Corporación de Fomento de la Producción (Geothermal Committee of CORFO); Instituto Antártico Chileno, del Ministerio de Relaciones Exteriores (Chilean Antarctic Institute, INACH) Servicio Agrícola y Ganadero, del Ministerio de Agricultura (Agricultural Service, SAG); and others. The main aspects of four projects (objectives, methodology, results) developed by the Remote Sensing Section, Department of Geology and Geophysics, Faculty of Physics and Mathematics Sciences, University of Chile, are summarized in this paper. All these projects are addressed to develope the most adecuate methodology to be adopted for every problem by using, as much as possible, the existing national infrastructure (persons and equipment). In this way, this Faculty is acting as an active focus for technology transfer in Chile.

The projects that will be summarized are: 1)Study of Environmental Conditions and Natural Resources in Antarctic Peninsula; 2) Study of Geothermal Resources in Los Andes Range; 3) Study of Snow-Water Resources in Los Andes Range, Central Zone of Chile; 4) Study of some Urban Traffic Problems in Santiago.

2. STUDY OF ENVIRONMENTAL CONDITIONS AND NATURAL RESOURCES IN ANTARCTIC PENINSULA

2.1. Preliminar Antecedents.

A Remote Sensing Program is being developed by Instituto Antártico Chileno (Chilean Antarctic Institute, INACH) and the Facultad de Ciencias Físicas y Matemáticas of Universidad de Chile since 1977 (Eng. M. Araya F., Chief of Program). This Program is directed to satisfy two main objectives: a) to improve the knowledge of the environmental conditions (meteorology, oceanography, etc) existing in Antarctic Peninsula, b) to improve the knowledge of natural resources existing in Antarctic Peninsula. Remote Sensing techniques are being used to satisfy both objectives: multispectral and multitemporal aereal and satellite images and Satellite Data Collection Systems have been experienced with good preliminar results.

The initial experiences of this program were directed to obtain experience and to furnish the adequate infrastructure to allow the operational use of this technology in antarctic conditions. During an operational stage, the Remote Sensing Program will serve as an auxiliar tool for the different scientific programs developed in Antarctic Peninsula under the INACH sponsoring and scientific guidance of Universidad de Chile and other technical and scientific institutions (biology, meteorology, glaciology, geodesy, logistics, oceanography, seismology, and other programs).

Satellite Data Collection Systems (DCS) were initially used in this program because of the existence of different facts: no aereal logistic capability in 1978/80; the existing infrastructure at NASA Station in Chile; the experience accumulated in using DCS in Chile since 1977; the permission of U.S. NASA and U.S. NOAA to use Landsat and GOES DCS in Chile; the urgent need to improve Chilean capability to collect and to distribute antarctic meteorological data. In this way all the initial efforts of this Antarctic Remote Sensing Program were conducted to deploy an experimental net of Data Collection Platforms (DCPs) to collect environmental data (meteorologic mainly) in an automatic, reliable and practical way from remote sites via satellite. Once aereal logistic capability would exist, the aereal and spatial observation levels (multispectral and multitemporal photographies and images) would be more intensively used, and so to be able to accomplish conventional ground measures with data collected via satellite (DCS).

2.2. Satellite Data Collection Systems (DCS).

As it is known (Paulson, 1976; Araya, 1978; Araya, 1979) a Satellite Data Collection System (DCS) is composed by three subsystems: a) several automatic ground sensing stations (Data Collection Platforms, DCPs) that automatically send their environmental data to the space in according to the updating and transmiting intervals programmed by the users; b) a satellite that relays DCPs data to a ground receiving station (orbiting characteristics of satellite are very important to determine the opportunity and quantity of data relayed); c) a central ground receiving station that receives processes and distributes DCPs data to the users via telex, telephone, ordinary mail (depending on the user's needs and capability to be linked with the central receiving station; usually the data is distributed in near real time).

The existence of NASA Station in Chile (Peldehue, about 40 km North from Santiago) was very important to perform this experiences. NASA Division personnel (affiliated to Facultad de Ciencias Físicas y Matemáticas, Universidad de Chile) allowed to modify this Station to work with Landsat/DCS (since 1977) and GOES/DCS (since 1980). An Experimental Program (headed by Eng. M. Araya F.) allowed to obtain valuable experience in 1977. Three DCPs were borrowed by U.S. Geological Survey (Dr. Richard W. Paulson and Dr. William D. Carter) to be installed in remote sites in Chile, and very good results were obtained. U.S. NASA and U.A. NOAA allowed to operationally use Landsat and GOES DCS in Chile. Nowadays NASA Division in Chile receives DCS data from about fifteen DCPs installed along Chile (five in Antarctic Peninsula) and due to their special cooperation the Antarctic DCS Program has been possible (Eng. Eduardo Díaz, Director and Eng. Heinz Martens, Chief of Users Programs).

In the Landsat mode it is possible to read the DCP sensors every 1-6 hours, to accumulate the information in DCP memory and to relay the data every 12 hours, when the satellite enters to zone of mutual visibility DCP-satellite-receiving station. In the GOES mode there is a more flexible and operational program to select update and transmission intervals (any value between 1 to 255 increments of 15 minutes); however it is usual to accumulate information in DCP memory and to transmit every 3 hours. The interrogable capability of GOES/DCS can not be used in Chile by now. For more details on Landsat and GOES DCS operation please see References Paulson, 1976; Araya, 1978; Araya 1979.

2.3. Main Antarctic DCS activities and Results.

The installation of an experimental net of DCPs in Antarctic Peninsula (fig. 1) has allowed to obtain very interesting results. The operational scheme to be used in Antarctic is showed in figure 2. Nowadays all the necessary links exist. In 1980 a poweful telemetric link was stablished by Chilean Air Force between Santiago (Comodoro Arturo Merino Benítez Airport, ex Pudahuel) and Antarctic Base Lt. Marsh (Antartic Regional Meteorological Center, A.R.M.C. Presidente Frei). Since 1980, NASA Station in Chile is able to work with Landsat and GOES DCS. The combined use of ships and airplanes (landing field in King George Island, near Marsh Base, existing since 1980) will allow to deploy DCPs further South in Antarctic Peninsula. If DCPs need to be installed more than 75 S, it will be necessary to use satellites having on board recording DCS capability or to install a central receiving station in Antarctic Peninsula (probably in ARMC Frei). In this sense, experimental programs with ARGOS system (TIROS-N satellite) are being programmed in the next future. By now only fixed DCPs have been used with Landsat and GOES Satellites. Before the operational use of the meteorologic data, it will be necessary to solve some problems related to environmental data quality that still remain. The main activities and results obtained until now can be summarized as follows. For more details please see References Araya, 1979; Araya, Vásquez, 1982; Araya, Radrigán, Brante, 1982; Araya, Rojas, Weber, 1982.

During February/March 1978, the first three DCPs were installed in Antarctic Peninsula. Two DCPs were installed at the A.R.M.C. Presidente Frei, in Lt. Marsh Base (DCPs 1,1' in the Fig. 1) and one DCP in O'Higgins Base (DCP 2 in Fig. 1). These were similar DCPs and it was necessary to install them near habitated basis to obtain experience on DCP operation under antarctic conditions. In this sense a more accurate

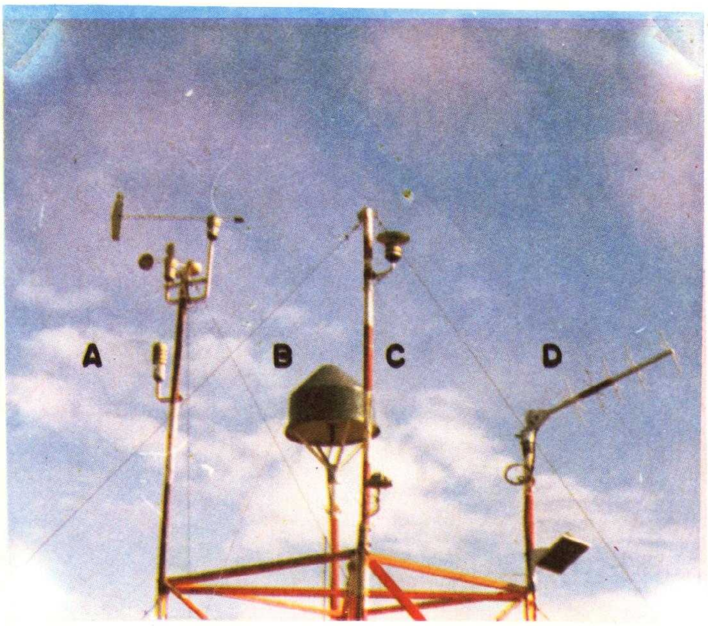


Photo 1. DCP at Marsh Base (A.R.M.C. Presidente Frei), 1978.

It is seen: a) mast with sensirs b) Landsat antenna c) mast with sensors d) GOES antenna .

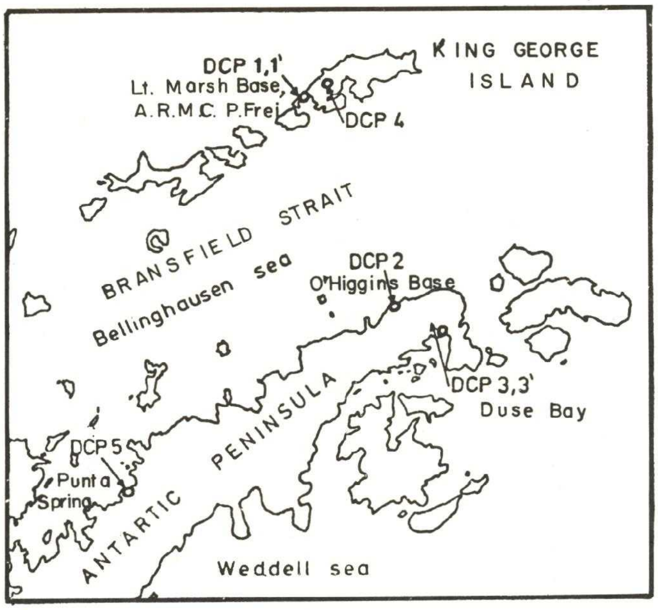


Figure 1. Location of DCPs in the pilot net deployed in Antarctic Peninsula (1978 - 1982).

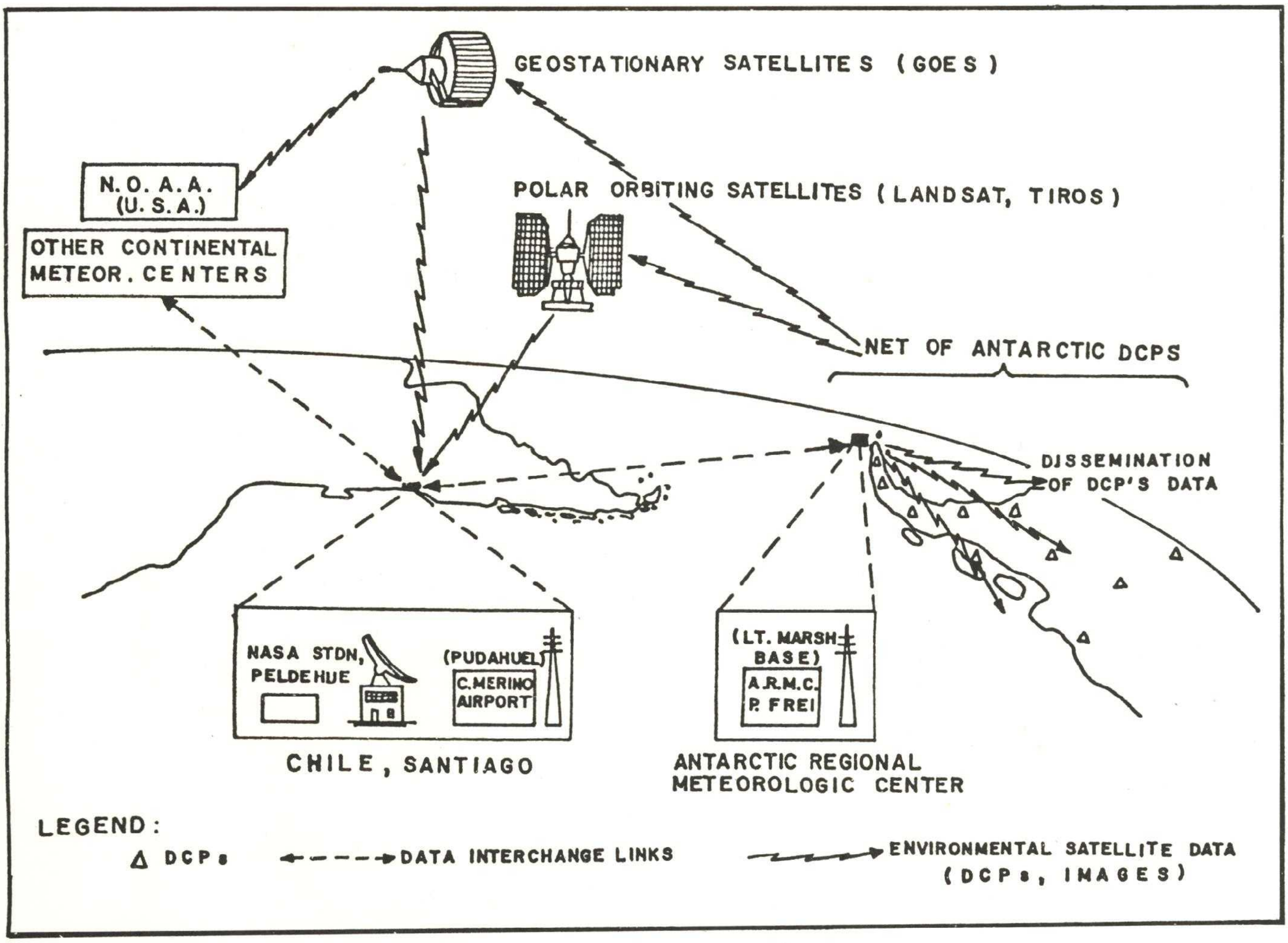


Figure 2. Operational scheme to be employed in the next future in Antarctic Peninsula to improve Chilean meteorologic data operation by using Satellite D.C.S.

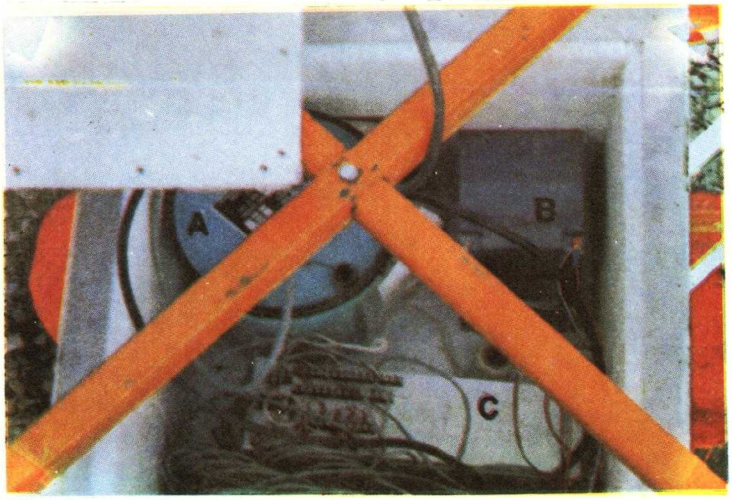


Photo 1b. Detail of protective box for elctronic devices .

It is senn : a) Convertible DCP b) set of batteries c) electronic interfases for different sensors.

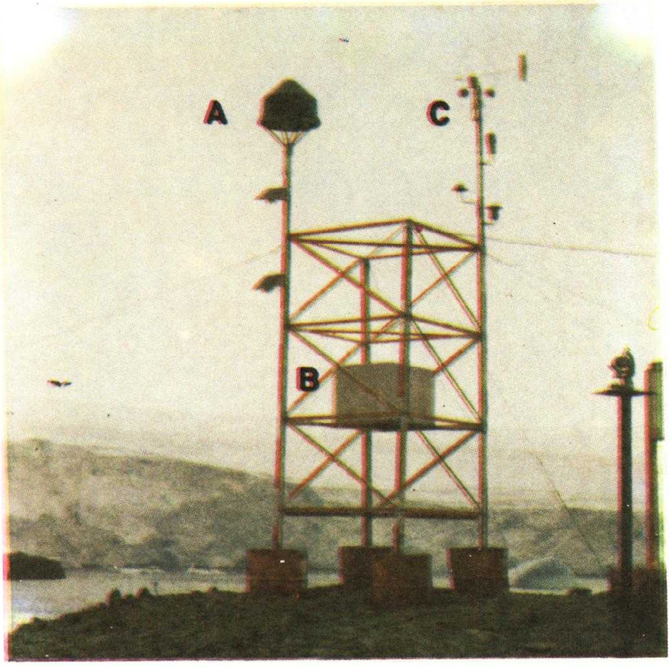


Photo 2. DCP in O'Higgins Base. It is seen: a)Landsat antenna b)protective box for DCP c) mast with meteorologic sensors

Photo 6. Installation of DCP in Punta Spring, January 1982.

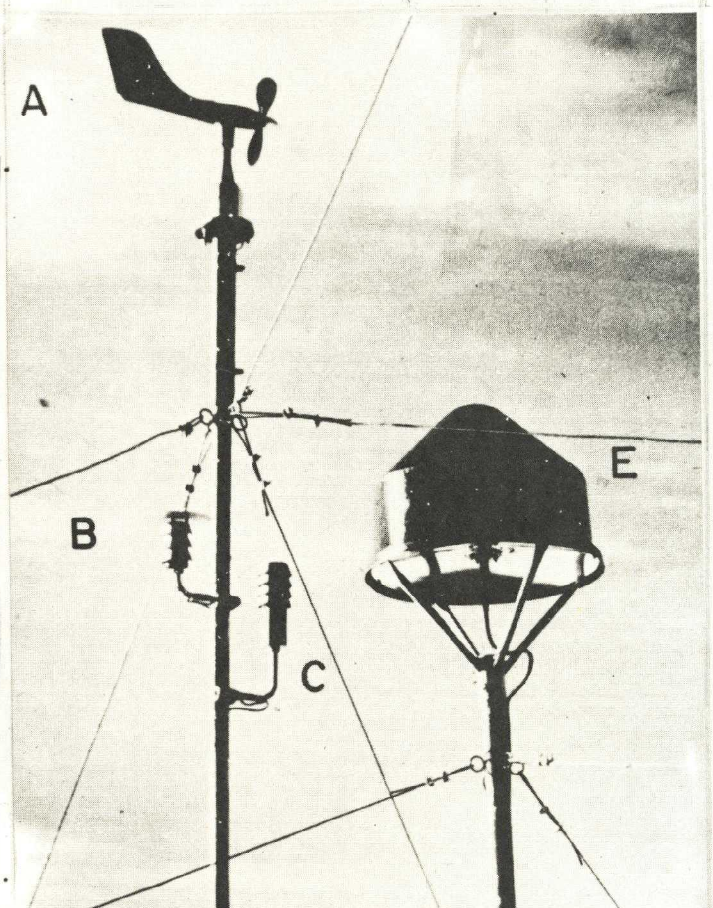


Photo 3. Detail of sensors of DCP installed at Duse Bay(1979-80). a)wind speed/ direction b)temperature c)air humidity d)solar radiation e) Landsat antenna .

Photo 4. View of the snow-truck from the DCP site,Weddel Sea Coast (1979).

was installed during february 1980 and operated with Landsat during 1980 and GOES/DCS was used during 1981. Valuable experience was obtained related to power supply (the same for Weddell DCP) and new type of sensors (Weathertronics Inc., USA). As a general result, power supply was adequate, Landsat and GOES DCS links were very satisfactory and sensors performance was improved but some problems on data quality still remained (specially air humidity/temperature). This DCP was installed with the valable cooperation of Antarctic Corp of Chilean Air Force and helicopters were used to perform very fastly this installation (specially Cap. Aníbal Tejos and Lt. M. Carvajal,R.I.P.). It was possible to furnish the logistic operation system to be used in the next future when airplanes be used to perform DCP installations further south in Antarctic Peninsula. Because the experimental stage of this DCP was accomplished, during summer 1982 it was removed to be installed further south, in Punta Spring.

The installation of DCP at Punta Spring (DCP 5 in fig. 1) was successfully performed last January 1982. GOES/DCS is being used in this experience. In spite of batteries problems did not allow to operate this DCP more than last March 1982, it was proved that it is quite feasible to remove a DCP and to install it again at a remote site. This operation (removing and installation) was performed in two weeks, by using marine trasportation. A new mounting structure was used in this opportunity, as showed in photo 6. During summer 1983, a new power supply and sensors kit will be used at this site to assure a correct performance for this DCP whose meteorlogical data is very important for scientific and navigation (aereal and marine) purposes.

2.4. Future Actions.

It is hoped that problems related to power supply at any latitude (by now there is not problem until 65S) and sensors reliability (data quality) be solved by 1984. Then, meteorologic data collected via satellite could be used in an operational way. By now, more experience will be acquired at more remote sites and more installations will be performed at southern latitudes during 1983 and 1984. Considering the actual capability of using airplanes to deploy DCPs, future actions are programmed in this sense. Besides, experience will be acquired with moving DCPs (drifting oceanic buoys, icebergs tracking) by using ARGOS system (TIROS-N satellite) in the next future.

Multispectral aereal photographies and images will be obtained during next summer 1983 (multiband camera and thermal infrared scanner); by now, important experience has been acquired in the use of these remote sensors in continental Chile (Araya, Piraces, 1982; Araya, Fernández et al,1982). Multispectral and multitemporal satellite images will be also employed to accomplish ground and aereal observation.levels. Landsat-D and SPOT capabilities have been considered for these future activities. The use of satellite images for cartographic purposes is a very important potential application. Important experiences have been performed by using geodetic satellites for the accurate positioning of ground control points (geoceivers that use Doppler effect); in this sense the Geodesy Program of INACH (Prof. Víctor Villanueva, Chief of Program) looks very promising.

PHOTO 5a. INSTALLATION OF DCP AT DUSE BAY,WEDDELL SEA COAST.

This DCP has been successfully operationg since 1980,by sensding meteorological data.

PHOTO 5b. DETAIL OF WEDDELL DCP MOUNTING STRUCTURE, WEDDELL SEA COAST (1980).

3. STUDY OF GEOTHERMAL RESOURCES IN LOS ANDES RANGE, CHILE.

There is an important geothermal activity in Los Andes Range along Chile. Depending on the latitude and the potential capability of the source, this energy could be used for different purposes. For instance in the desertic North of Chile, this energy could be a good alternative for energy generation, because no hydroelectric generation it is possible and petroleum must be used to move the existing thermal centrals for electricity generation. Touristic purposes are also important to promote regional development, above all in the Central and South Zones of Chile, where important water supply exist for hydroelectric generation.

Interesting experiences have been performed to study geothermal resources by using remote sensing techniques in Chile. Promising results have been obtained in the detailed study of identified geothermal fields (exploration stage) by using airborned remote sensors (multiband camera and thermal scanner). In the other hand, the use of multispectral and multitemporal Landsat images over snowed areas in the Chilean Central Andes, has allowed to successfully identify new geothermal areas (prospection stage). The extrapolation of these results allow to think in the successful development of a national (and continental) program to study geothermal resources by using remote sensing techniques. These studies have been performed in the Remote Sensing Section, Geology and Geophysic Department, Faculty of Physic and Mathematics Sciences, Universidad de Chile (Eng. M. Araya, Chief of Project; Prof. V. Villanueva), with the close participation of Aerophotogrametric Service,SAF (Cnl. Jaime González, Cm. Sergio Carrasco, Com. Hernán García) and the Geothermal Committee of CORFO (Geologist Raymundo Piraces, Chief National Cadaster Program). The main aspects and results of these experiences can be summarized as follows.

3.1. Detailed Studies (exploration stage): Use of Airborned Remote Sensors at El Tatio.

This was the first experience related to the study of geothermal fields by using remote sensing techniques performed in Chile. El Tatío geothermal field, about 1.200 km N.W. from Santiago (fig. 3) was selected as a test site because is the most studied geothermal field in Chile and in this way it would be easier to verify the information obtained through multiband camera and thermal scanner (Lahsen, 1976; Lahsen, Trujillo, 1975). A S.A.F. Twin Otter airplane was used to carry the remote sensors and a portable field photographic laboratory that was set up at Calama Airport, the operation center for this experience (about 80 km East from El Taio). Multispectral photographies and thermal images were developed almost in real time and so it was possible to verify the correct overlap between flight lines, to decide what specially interesting zones should be flown at lower altitudes(thermal features)and to better planing the field verification activities. The technical crew (Cap. James Juica, Lt. Juan Espinoza, Lt. Carlos Voigt, Lt. Carlos Piraino, Sgt. Carlos Velásquez, Sgt. Héctor Garrido) and scientists (Geologist Raymundo Piraces, Prof. Victor Villanueva, Eng. Mauricio Araya, Chief of Project) remained during one week in the zone and when all the necessary information was obtained it was returned to Santiago. This field operation methodology was very useful and will be used for future operational projects.

The multiband camera allowed to obtain a real view of the terrain (without deformation), at an original scale 1:7.000(app.). The bands were:AMB-1 or blue(0.4-0.5 um),AMB-2 or green(0.5 0.6 um), AMB-3 or red (0.6-0.7 um), AMB-4 or near infrared (0.7-0.9 um). As it is seen, there are similar conditions with Landsat spectral Bands MSS-4 (AMB-2), MSS-5 (AMB-3) and MSS-6 (AMB-4). Photo 7 shows an example of multiband photography over El Tatio zone. Mosaics were made with spectral bands AMB-2,3,4. This information was used in B/W products and color composites (Diazo techniques). In spite of no digital processing could be made, the photographic quality of both multiband photographies and thermal images was enough good to obtain satisfactory results.

Meanwhile multiband photographies were obtained at the conventional daily aerophotogrammetric hours, thermal images had to be taken very early in the morning, before sunrise, to avoid distortions in registering emmited energy. At this hour, the temperature contrast is excellent because of the altitude of El Tatio geothermal field (about 4.500 over sea level), the air temperature is some ºC minus zero and the boiling water is about 86ºC (photo 8). Then, all the material having an inner energy will appear clearly more hot (white tones in original B/W images). The thermal infrared linescanner operated in the spectral band 8-14 um and in spite of its direct register of data in B/W film, the quality of these images was really excellent (temperature discrimination or R.M.S. 0,25º C ,spatial resolution or I.F.O.V. 1,5 milirad), as seen in photo 9. Thermal images were obtained at an original scale ,approx., 1: 10.000 (longitudinal or flight direction) and 1: 25.000 (transversal or cross flight direction). This spatial distortion was not a problem for data interpretation because it was possible to correlate this information with the undistorted multiband photographies. The combination of both type of information (processed with analogic techniques, for B/W and color products) allowed to obtain a map with the main geologic structures (faults and linements) at El Tatio geothermal field (Photo 10, Figure 4). In spite of some field verification activities are necessary yet, this map is very reliable because thermal images have excellent characteristics to show geologic structures that do not have a good

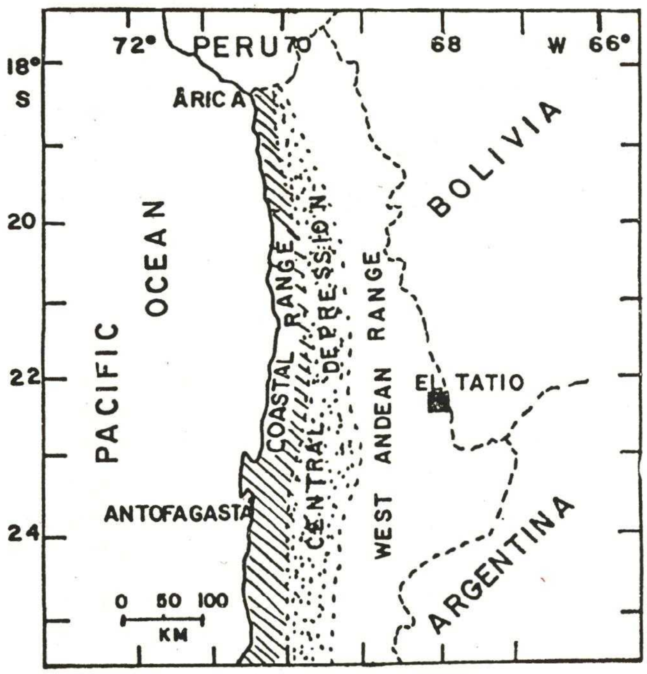


Figure 3. Location of El Tatio geothermal field, in the desertic North of Chile.

Fig. 7 - Área urbana obtida em 197,

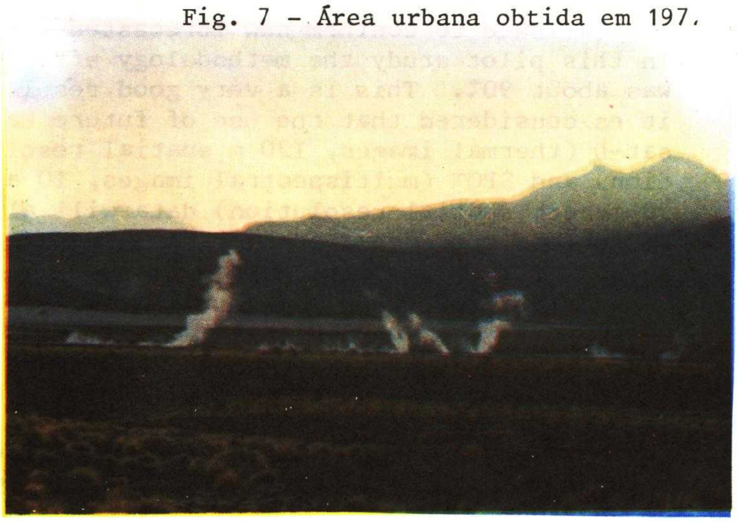


Photo 8. Geothermal energy(geyser) as seen in El Tatio , in the early morning.

Photo 9a. Thermal infrared image over El Tatio (original format). Hot drainage and thermal structures (including faults showed through alignement of hot springs) are clearly seen in white tones.

Photo 7. Multiband photography over El Tatio geothermal field.
In this scene over a geyser area, spectral bands AMB-3 or red (0.6-0.7 um) and AMB-4 or near infrared (0.7-0.9 um) are showed. Salty soils are seen in white tones. This information was very useful to be compared with thermal images (usually spatially distorted). Color composites (Diazo techniques) were also used to better distinguish different matterials (soils, salts, vegetation, water).

stratigraphic control to be recognized in the field. Usually the alignement of hot water springs (as showed in photo 9) or the high thermal contrast between different rock units allow to clearly identify important geologic structures. As a general conclussion, if this information be available in the first steps of the exploration activities of a geothermal field, many time, efforts and money could be saved because this information is very useful to plan the preliminar field geologic activities. Thermal images are a key element to recognize geologic structures associated to geothermal fields. For more details on these experiences, please see References Araya, Piraces,1980: Araya, Piraces, 1982.

3.2. Regional Studies (prospection stage): Use of Landsat Images in Del Maule Lagoon.

Because of the high level of geothermal activity in Los Andes Range, Chile, it was necessary to develop a low cost methodology to find new areas of geothermal activity because aereal recognition would be very expensive for these purposes. Then, when a potential area be found, aereal activities could be developed depending on the importance of that geothermal field. In Del Maule Lagoon, Central Zone of Chile (fig. 5), a test experience was developed and promising results were obtained. The use of multispectral and multitemporal Landsat images was decisive to successfully develop this experience. It was possible to determine a methodology to identify potential areas of geothermal activity with a high accuracy lavel, at regional scales 1:250.000 (Landsat images). This methodology is based on the observation of abnormal snowmelting areas, near volcanic structures, and it is useful to be applied in zones where an important distribution of snow occurs along the year (typical situation of Central Zone of Chile). Four Landsat images were used in this experience (false color composites, 1:250.000). These images were acquired in INPE, Brasil and it were representatives of different snow conditions along a year (Sep. 6,1977;Dec. 9,1978:Apr. 19,1978;Feb. 1,1979).

It is necessary to correlate permanent features (geologic faults and linements, volcanic structures, hydrothermal alteration zones, identified geothermal sources, topography, hydrologic net) and variable features (distribution of snow near volcanic areas,variation of water bodies and vegetation spots in snowed areas). Three steps must be followed to obtain results: 1) Compilation of geologic antecedents (permanent features). All the existing information (geologic maps, geothermal antecedents, topographic maps, etc.) and the new information derived from Landsat images (volcanic structures, geologic faults and linements,etc.) must be used to obtain a good reference on permanent features. 2) Analysis of Variable Features. Identification of specially interesting zones such as: areas where liquid water remains abnormally uniced, areas with abnormal distribution of vegetation in snowed areas,etc. The proximity of volcanic structures is a key element to be considered. 3) Integral analysis of Antecedents. The information obtained in the former steps (usually resumed in two special transparent maps) must be carefully compared and integrated to obtain a final map containing the potential areas of geothermal activity. Sometimes it is possible to confirm or to discard a potential area through the only analysis of the existing information compiled in steps 1 and 2. Otherwise only a field trip will solve the doubt.

It is important to notice that this methodology does not assure 100% accuracy for the forecasts of potential areas of geothermal activity. However it allows to reduce the areas to be explored with more detail. Photo 11 shows the area of pilot studies near Del Maule Lagoon; some special water springs, near volcanic structures can be appreciated. Figure 6 is a map with the main results. Potential areas forecasted were successfully confirmed because existing (identified) thermal springs were included in these areas and field activities allowed to conform new forecasted areas. In this pilot study the methodology efficiency was about 90%. This is a very good result if it es considered that the use of future Landsat-D (thermal images, 120 m spatial resolution) and SPOT (multispectral images, 10 and 20 meters spatial resolution) data will allow to perform more detailed and complete studies. By now, this is a very convenient methodology to acquire experience and to begin its operational use when more accurate satellite images data be available. In this sense, more pilot zones will be studied along Chile because snow distribution conditions are very different from North to South in Chile. In this way, a general methodology, valid for the whole country, could be developed.

3.3. National and Continental Programs.

Based on the good results obtained formerly, a general methodology will be intended for the whole country. Five more pilot areas will be studied (fig. 7) thanks to the partial sponsoring of Servicio de Desarrollo Científico de la Universidad de Chile (Service for Scientific Development, University of Chile). Landsat1,2,3 images will be used as statistical information for a system of volcanic surveillance. This information will be very useful over snowed areas, as shown in example of photo 12. The final general objectives of this program would be: 1) to obtain a national cadaster on geothermal activity, at least at a regional scale 1:250.000 2) to stablish a permanent surveillance system for volcanic activity 3) to intend to stablish a correlation model between volcanic and sismic activity (statiscal data). To accomplish these objectives, three steps should be followed: a) Experimental Stage or Landsat 1,2,3 data (1980/82): it will

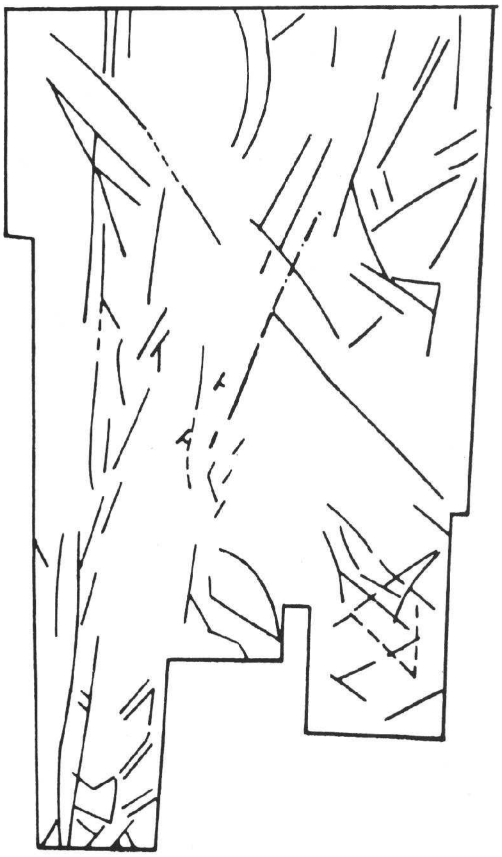


Figure 4. Main geologic structures(faults and linements) derived from thermal mosaic and multiband photographies(partial result)

Photo 10. Thermal mosaic (half southern sector) of El Tatio geothermal field (approx. scale 1: 100.000, actual).

Different units are shown through the heat loss charcateristics. This mosaic is a key element to identify geologic faults and linements.

Photo 9b. Thermal image over El Tatio zone.

Hot drainage (white tones) and hot water springs are clearly identified.

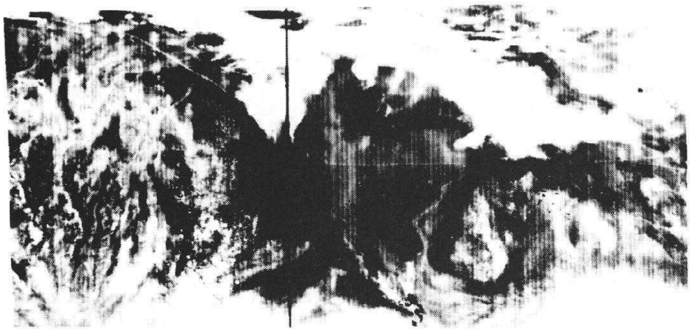


Photo 9c. Thermal image over El Tatio zone.

Different rocks or soil units are identified trough different heat lost characteristics.

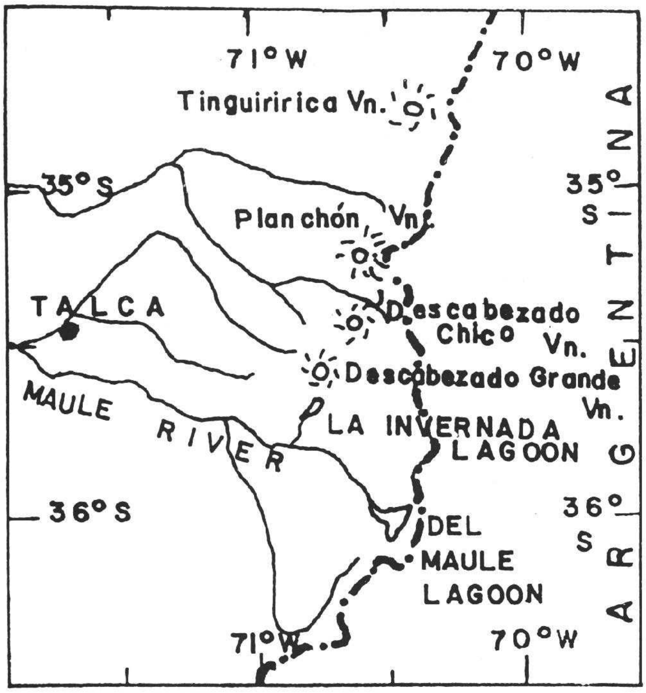


Figure 5. Location of Del Maule Lagoon, and Invernada Lagoon. Test zone to identify geothermal activity through Landsat images.

Photo 11. Pilot zone over La Invernada Lagoon sector, to identify geothermal activity through Landsat images. Abnormal snowmelting areas (vegetation spots, water bodies,etc.)near volcanic zones are key elements to be considered.

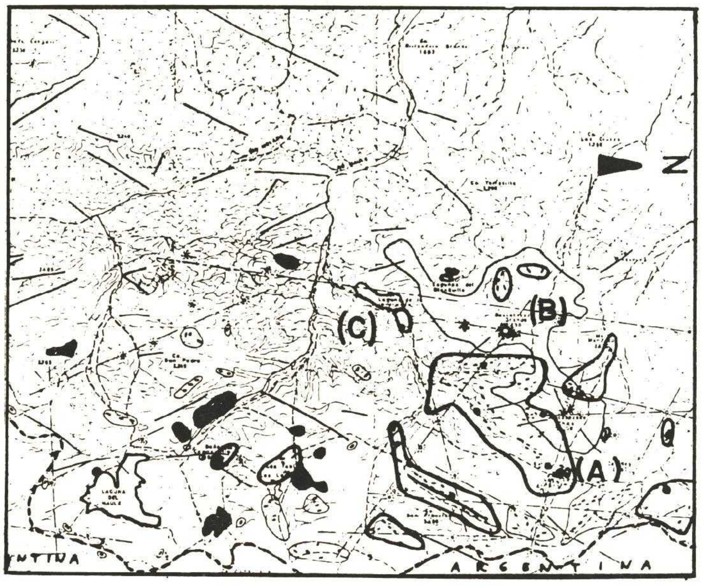


Figure 6. Map showing main results over Del Maule and La Invernada Lagoons sectors.

The potential areas for geothermal activity (surrounded by gross black lines) were identified through this methodology. Black spots inside these areas indicate the existence of geothermal springs (formerly identified or recognized in the field). The good results obtained prove the potential value of this methodology.

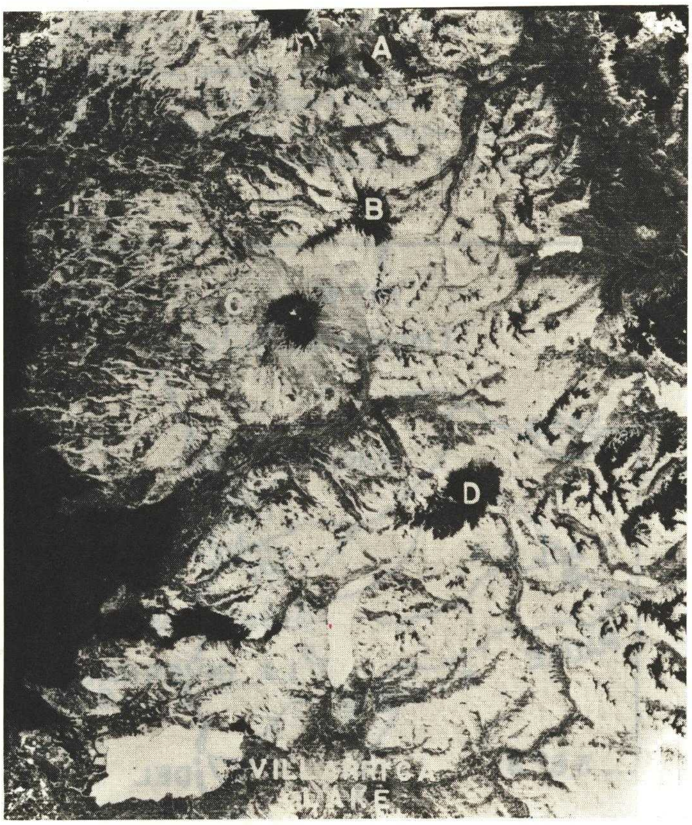


Photo 12a. Portion of Landsat image over Villarrica zone, South of Chile. This MSS-5 scene (March 4,1973) over this volcanic area shows normal distribution of snow.

Photo 12b. Band MSS-7 over the same zone of photo 12a, clearly shows the abnormal snowmelting over active volcanes (indicated trough the humid soil, in black tones).

be possible to define general methodology based on the results obtained through the study of six pilot zones from North to South in Chilean Andes Range; b) Semi-Operational Stage or Landsat-D data (1982/84): thermal images data will be very useful to help to define the general methodology through the study of the six pilot zones; c) Operational Stage or SPOT data (since 1985): the improved spatial resolution of SPOT images will accomplish Landsat-D data and so to define the general methodology to be operationally applied in Chile.

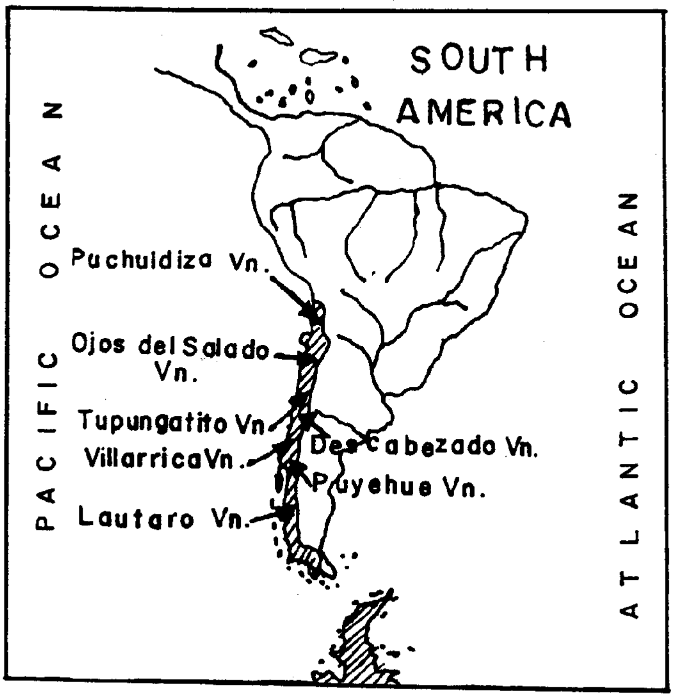


FIGURE 7. PILOT VOLCANIC ZONES TO BE STUDIED IN CHILE .

In this way, a general methodology will be developed for the whole country .

Based on the former considerations for the national program, it would be feasible to intend to apply similar methodology and objectives to study other regions in the planet (of course by doing the necessary modifications, depending on the special environmental characteristics of every region or country). The study of geothermal or volcanic activity in Los Andes Range in America, could be an interesting program to be executed through a regional cooperation, considering the theluric activity in the Pacific Ocean Basin. In this way it would be possible to contribute to the global knowledge of this important zone of the planet (of course, statistical data would be necessary). This scientific continental program could be stablished by using the existence of the Sociedad de Especialistas Latinoamericanos en Percepción Remota,SELPER (Society of Latinamerican Expertises on Remote Sensing) as an integration facility. The use of Satellite Data Collection Systems (DCS) would be very useful in this type of programs (specially interrogable DCPs for GOES/DCS).

4. STUDY OF ANDEAN SNOW-WATER RESOURCES, FOR SNOWMELT RUNOFF FORECASTS.

A pilot project is being developed to determine the best methodology to use Landsat images as an auxiliar tool to improve the snowmelt runoff forecasts in Los Andes Range, Central Zone of Chile. This pilot project is a joint program between Dirección General de Aguas, DGA (National Water Survey ; Eng. Humberto Peña and Eng. Javier Narbona) and Remote Sensing Section of Geology and Geophysic Department, Faculty of Physics and Mathematics Sciences, Universidad de Chile (Eng. Alejandro Farías and Eng. Mauricio Araya, Chief of Program). Once this general methodology be determined, DGA will operationally use satellite images in their normal activities. It is hoped to have definitive results by ending December 1982. The main aspects of this pilot project can be summarized as follows.

There is an important need to evaluate the snowmelt runoff because during the dry season (summer, November-April) the water supply for the Central Zones of Chile depends on the snowmelting (no rainfall occurs during this period). The Chilean Central Zone (approx. from Vallenar, 29° S, to Los Angeles, 38° S) is the most important area for agriculture and the main power supply is represented by hydroelectric generation centrals. Because of the difficulties to obtain ground truth data on snow conditions, Satellite Data Collection Systems (DCS) are being experienced by Dirección General de Aguas (DGA). There are two pilot nets of DCPs in the Central and North Zone of Chile (6 DCPs). These experiences began on 1977 and some details still remain for the operational deployment of DCPs along Los Andes Ranges. Landsat and GOES D.C.S. data is being received at NASA Station near Santiago.

Other important program of D.G.A. is the evaluation of Landsat multispectral/multitemporal images for improving snowmelt runoff forecasts. In this sense a joint program is being developed, as it was said at the begining of this point. This program intends to evaluate Landsat data (DGA has a data bank of Landsat images, monthly base, since 1977 to 1980) and to determine the most adequate methodology to be used in the next future, in an operational way. The evaluation will be in terms of costs, time, accuracy, easiness to apply. After the best methodology has been defined to determine the different parameters (such as snowcoverage, altitude of snow line, etc.), the correlation models will be stablished for every water basin. The main activities to be performed in the next months can be resumed as follows.

a) Three pilot basins will be used: Elqui River, Maipo River and Ñuble River (fig.8) The basins and sub-basins will be defined at scales 1: 1.000.000, 1: 500.000,1:250.000, 1:100.000 and 1:50.000 (if possible). Supervised Landsat images and existing cartography will be used for these purposes.

b) Determination of the most adequate methodology (in terms of costs, time, efficiency, accuracy) to measure snow coverage parameters(% of snowcovered basin, altitude of snow line, differences between MSS-5 and MSS-7 areas, etc.). Several alternatives are considered and will be evaluated (zoom transfer scope, slides and transparencies projections, digital evaluations, etc.).

c) Determination of the most representative parameters to be used in the correlation models (altitude of snow line, % snowcovered basin, etc.).

d) Stablishment of cuantitative correlation models by using Landsat derived information (snow conditions) and ground existing data (river stage, snow-water equivalent, meteorologic information, etc.).

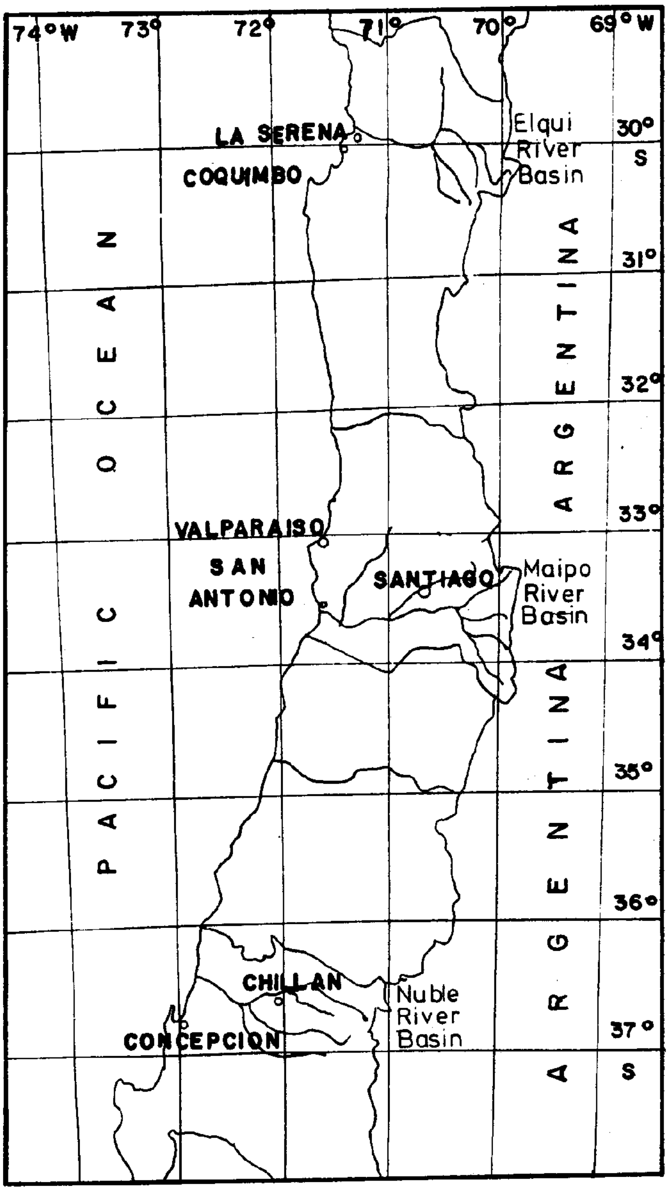


Figure 8. Location of Elqui River, Maipo River and Ñuble River Basins.

Because Chilean Andean Basins are rather smalls and due to significative differences on annual snow distribution (depending on latitude, longitud,altitude over sea level), it will be necessary to study several basins to stablish general results valids along the country. It is hoped that by ending 1982, significative results will be obtained for these three representatives watersheeds of Chilean Central Zone. In the next future, Landsat-D and SPOT data will be very useful to obtain more accurate and detailed results (scales 1:50.000 for instance). By now it is necessary to determine the best methodology and so to operationally use Landsat-D and SPOT when this information be available.

5. STUDIES OF SOME URBAN PROBLEMS IN SANTIAGO BY USING AIRBORNE REMOTE SENSORS.

A cooperation agreement between Servicio Aerofotogrametrico (SAF) and Facultad de Ciencias Físicas y Matemáticas, Universidad de Chile (Remote Sensing Section) has allowed to perform several interesting experiences related to some important urban problems in Santiago, Chile. The objective of these experiences is to develop appropiate methodologies for application in future operational projects.

The use of multiband camera and thermal infrared scanner, mounted on a SAF Twin Otter, has allowed to determine basic parameters related to environmental pollution. Potential sources of smog (and its relative importance) are clearly identified in thermal images. A thermal map of a zone of Santiago has been developed allowing for real updated view of the different hot sources and its relative contribution to atmospheric pollution. It can be seen that residential areas have several small hot sources (chims, etc.) meanwhile suburbs have a small number of big hot sources (industries). Pollution of water streams can also be identified very clearly in thermal images and some dramatic examples have been collected over Mapocho River in Santiago. Photo 13 shows some example on environmental pollution. The same technique has showed its potential value to identify problems on building isolation and the related potential energy saving during winter time. It has been also determined the ability of near infrared band to penetrate light fog, on multiband photographies. Both multiband camera (vegetated areas) and thermal scanner are very useful for these studies.

The use of conventional aereal B/W photographies has allowed to obtain very promising results on the use of this information to identify and to quantify problems of urban traffic, specially those problems of vehicle congestion. It has been possible to essay a methodology to evaluate vehicle concentration and its temporal and spatial distribution at the peak hours. This study has been performed with the valuable participation of the Transportation Section, Civil Engineering Department, Faculty of Physics and

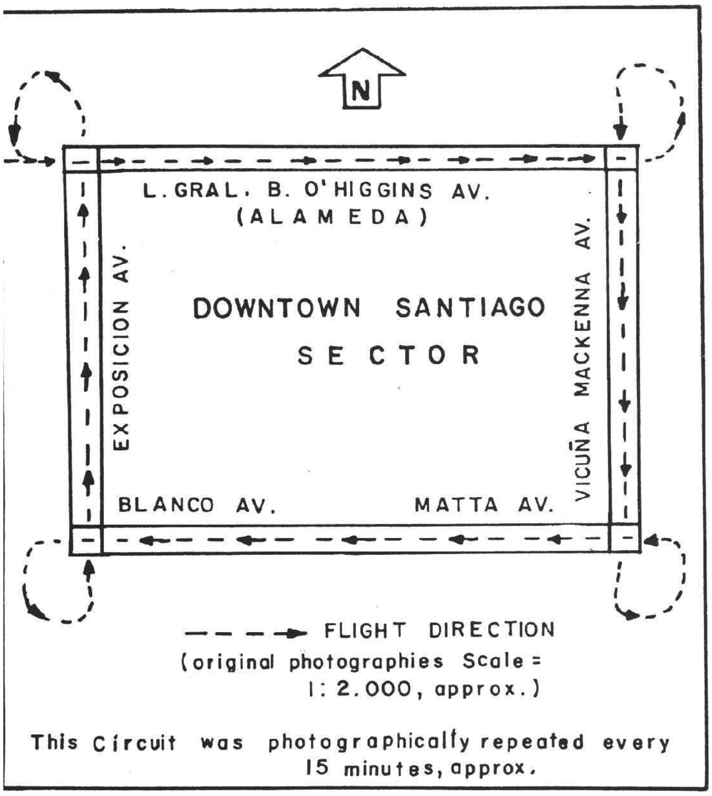


Figure 9. Circuit over downtown Santiago used as test zone for urban traffic studies. Aereal photographies, B/W were taken every 15 minutes since 7:30 to 10:00 A.M.

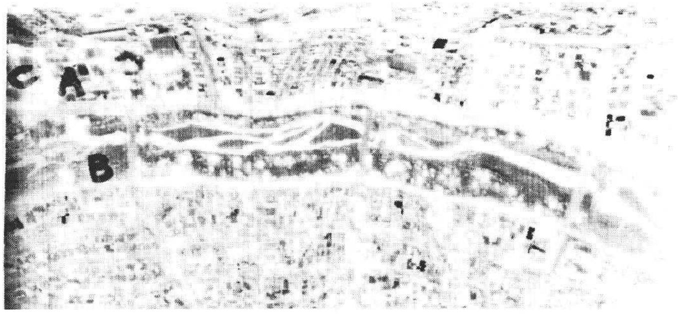


Photo 13a. Thermal image over Mapocho Rive area, Santiago, showing water pollution. Tl industry (c) uses the water of San Carlos channel(a) and the hot stream is entered t Mapocho River (b)to increase river tempera ture.

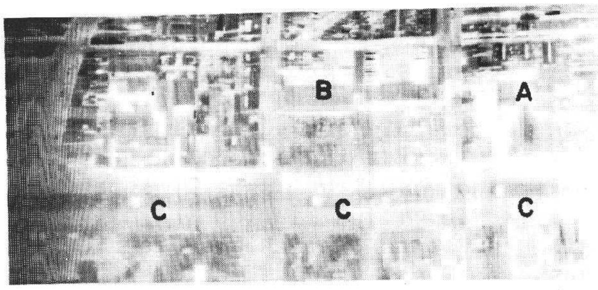


Photo 13b. Thermal image over Santiago, sh ing the activity of an industry (a), a bu terminal (b) and the air chims of the met politan subway(c).

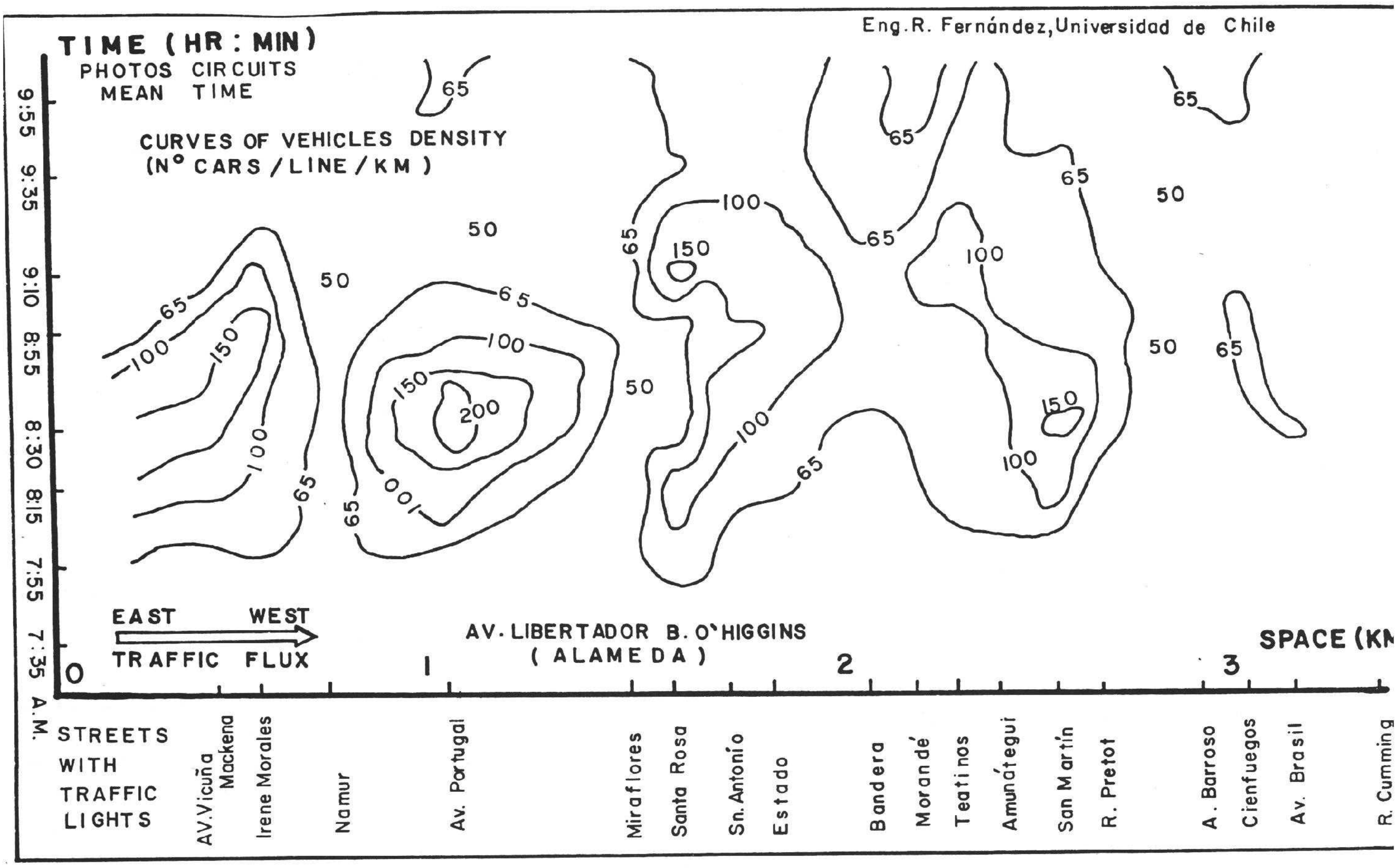
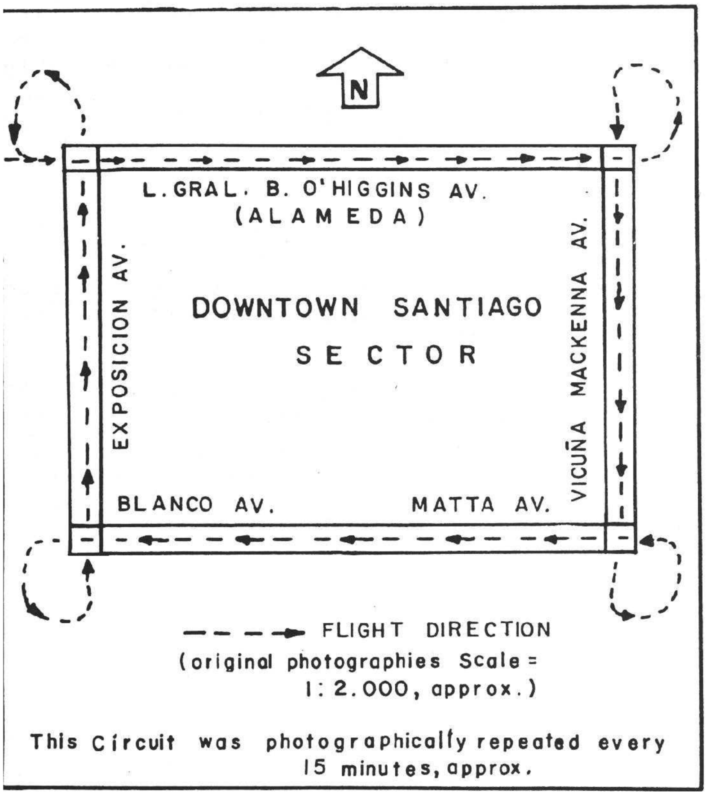


Figure 10. Partial results (private vehicles) over Bernardo O'Higgins Avenue (Alameda). The curves of isoconcentration of vehicles (spatial and temporal distribution) really are representatives of the traffic conditions in this downtown Santiago avenue. Identification of special problems allow to study the most appropiate solutions.



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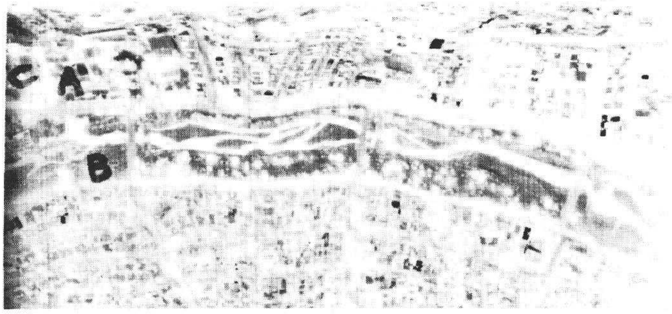

Photo 13a. Thermal image over Mapocho River area, Santiago, showing water pollution. The industry (c) uses the water of San Carlos channel(a) and the hot stream is entered to Mapocho River (b) to increase river temperature.

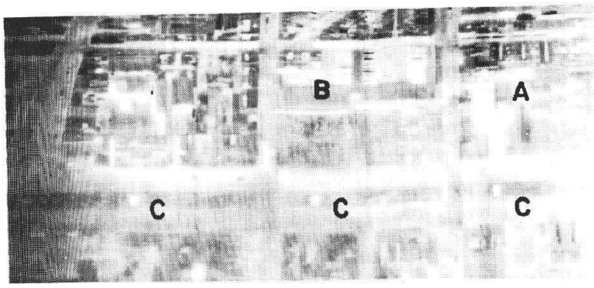

Photo 13b. Thermal image over Santiago, showing the activity of an industry (a), a bus terminal (b) and the air chims of the metropolitan subway(c).

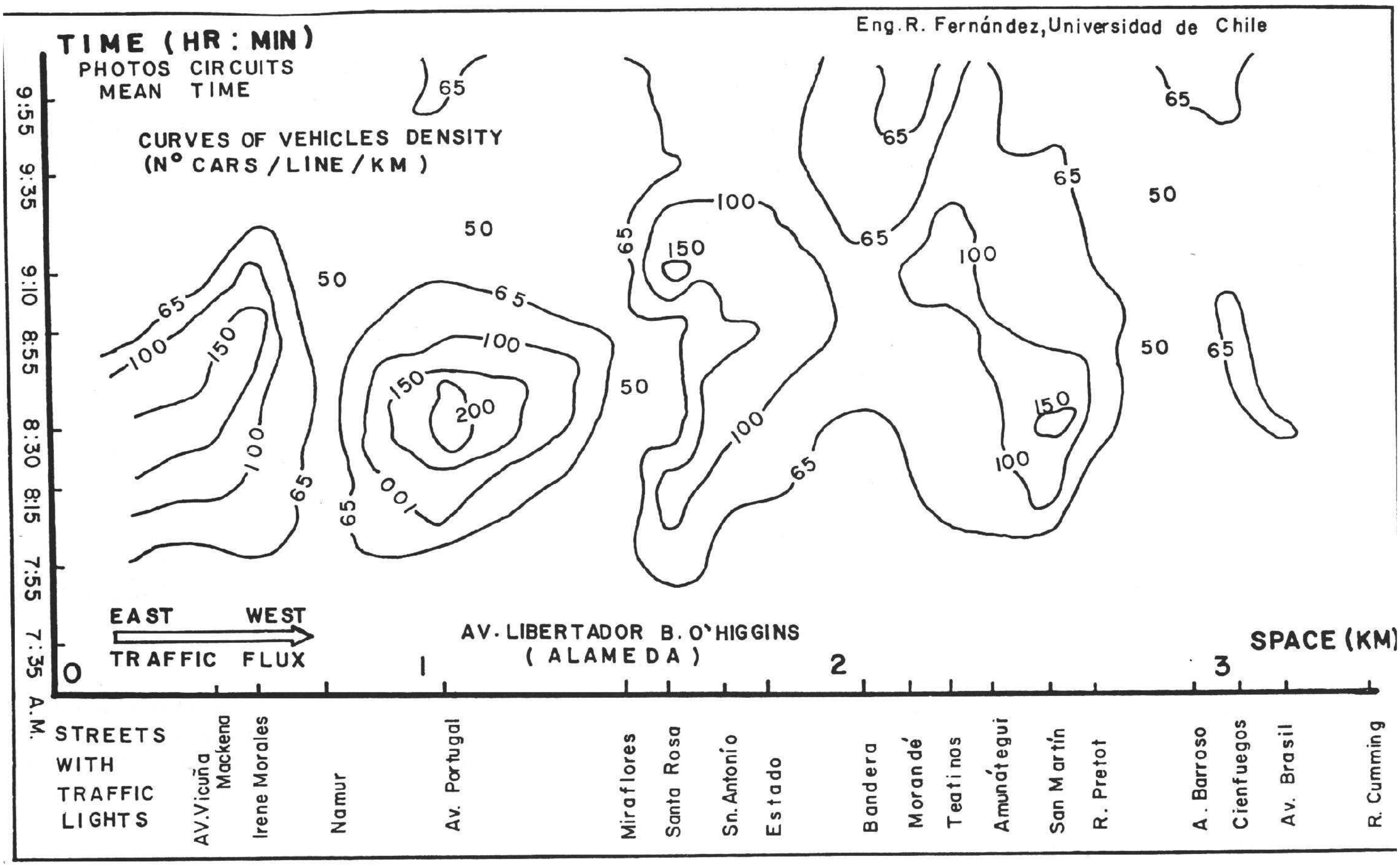

Figure 10. Partial results (private vehicles) over Bernardo O'Higgins Avenue (Alameda). The curves of isoconcentration of vehicles (spatial and temporal distribution) really are representatives of the traffic conditions in this downtown Santiago avenue. Identification of special problems allow to study the most appropiate solutions.

Mathematics Sciences, Universidad de Chile (Eng. Jaime Gibson; Graduating Engineers Nelly Nussbaum and Rodrigo Fernández, Remote Sensing Section). The valuable cooperation of Servicio Aerofotogramétrico was again decisive to successfully accomplish this experience (specially Com. Hernán García and Com. Sergio Carrasco). A pilot circuit (fig. 9) was choosen to evaluate this methodology. This zone of downtown Santiago is specially congested at the typical peak hours (morning, midday and afternoon). Because of light conditions (September 1981) the morning period was selected to perform the experience. This circuit was flown every 10-15 minutes since 7:30 A.M. to 10:00 A.M. A time-space diagram with vehicle isoconcentration curves was built, by using conventional B/W photographies (app. scale 1:2.000, but 1:10.000 would be enough). Congestion evolution (in time and space) along a specific street can be avaluated and bottlenecks could be studied to find adequate solutions. The example showed in figure 10 is a typical result of this methodology (Eng. Rodrigo Fernández, Nelly Nussbaum; supervision Eng. Jaime Gibson and Maurico Araya). This graphic represents the vehicle distribution from East to West, private vehicles, in Bernardo O'Higgins Avenue (Alameda). The different isoconcentration curves were built for every block and the congestion level is given by the number of vehicles/strip/km. For instance, a congestion level 200 indicates 200 vehicles/line/km (that is, only 5 meters for every vehicle). These graphics were built for buses, cars, both type of vehicles, and for both senses of traffic (six graphics for street). The real situation is very well represented in these graphics and valuable new information can be obtained from this interpretation. In spite of this methodology is being more accurately evaluated by now, it can be said that it will represent a very valuable new contribution to study urban traffic problems in Chile. It is hoped that this technology could be operationally used in the next future.

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