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P18

REMOTE SENSING, GEOGRAPHIC INFORMATION SYSTEMS AND GLOBAL POSITIONING SYSTEMS. THEIR ROLE IN LAND USE/ENVIRONMENTAL PLANNING AND MANAGEMENT IN THE SOUTH PACIFIC REGION

TELEDETECTION ET SYSTEMES D'INFORMATION GEOGRAPHIQUE : LEURS ROLES DANS L'UTILISATION ET LA GESTION DES SOLS ET DE L'ENVIRONNMENT DANS LA REGION DU PACIFIQUE SUD

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ABSTRACT

Countries of the Pacific region are characterised by land masses which are surrounded by vast areas of ocean. This unique geographical relationship creates management problems that are peculiar to the region. The isolated nature of the land areas means that conventional methods of data collection such as aerial photography are not undertaken at regular intervals. Such repetitive coverage is necessary for efficient resource management practice. In addition, imaging in parts of the spectrum other than the visible is almost unknown. Remotely sensed data acquired from satellites is particularly suited to this situation. Data derived from such systems can provide repetitive, timely and accurate information about the earth and atmosphere at a variety of spatial and temporal resolutions. Data collection alone is not enough however. Such data need to be integrated and evaluated with other data sets so as to provide reliable decision making information. In addition, the regular coverage that satellite systems can provide means that large volumes of data are produced and must be handled efficiently if maximum benefit is to be achieved. Geographic information systems provide the answer to both of these situations.

Integrating these two technologies, while providing high accuracy ground control via global positioning systems gives a powerful resource management tool termed a Geographic Information Processing System.

In conjuntion with Riedel and Byrne Consulting Ebgineers, the RMIT Centre for Remote Sensing has commenced a research programme aimed at establishing a geographic database over the island of Tongatapu, using a Geographic Information Processing System. SPOT multispectral and panchromatic data is being used to augment existing data sets in the creation of the database. Once completed the database will be used to model a variety of resource management scenarios.

The technologies used in this project are relatively inexpensive. It should therefore be possible for this programme to be extended and the countries involved to become responsible for the compilation and maintenance of their own geographic databases. One of the goals of this project is therefore to implement a methodology for technology transfer.

RESUME

L'isolement et la vaste répartition géographique des pays du Pacifique implique que les méthodes classiques de collecte d'information (par exemple, la photographie aérienne) sont coûteuses et inappropriées. Ceci a fait que les levés aériens n'ont pas été acquis aussi fréquemment qu'il aurait été nécessaire pour contrôler les modifications de l'environnement et de l'utilisation des sols. Les données télédétectées recueillies par satellite sont particulièrement adaptées à cette situation. L'on peut avoir une couverture régulière à un prix raisonnable et une résolution spatiale adaptée. Ces informations peuvent être analysées afin de produire des données allant de la profondeur et de la qualité de l'eau à l'évaluation du couvert terrestre. La couverture régulière fournie par les systèmes satellites implique que de grandes quantités d'informations sont produites et doivent être gérées efficacement si l'on souhaite en tirer le plus grand profit. Les systèmes d'Information Géographique peuvent servir de véhicule pour la gestion efficace de ces données.

Conjointement avec les Ingénieurs-Conseil Riedel et Byrne, le Centre de Télédétection RMIT a commencé un programme de recherche visant à établir une base de données géographiques sur l'île de Tongatapu en ayant recours aux technologies de la télédétection et des systèmes d'information géographique. L'on a utilisé les données multispectrales SPOT pour compléter les séries d'informations déjà existantes, telles que le type de couverture et la bathymétrie côtière. Les informations obtenues par ce procédé ont été introduites dans un PC - Arc/Info, un Système d'Information Géographique à base vecteur. Ce document explicite les résultats acquis jusqu'alors, et présente quelques applications de cette base

de données dans le domaine du contrôle de l'environnement et de l'utilisation des sols.

Les technologies employées dans ce projet sont relativement peu coûteuses. De ce fait, il devrait être possible d'extrapoler ce programme et d'envisager que les pays concernés se chargent de la compilation et de l'entretien de leurs propres bases de données géographiques en faisant l'acquisition du matériel informatique et des logiciels nécessaires. L'un des objectifs de ce projet consiste donc à mettre en oeuvre une méthodologie de transfert de technologie au moyen de laquelle les urbanistes et gestionnaires locaux de la région pourront être formés à la réalisation de leurs propres bases de données.

INTRODUCTION

The countries of the Pacific region are characterised by small land areas with vast areas of ocean. Land is therefore a precious resource and needs to be managed as efficiently as possible to ensure continued and sustainable development. Considering that these small areas of land provide much of the regions exports, up-to-date information on infrastructure, productivity and condition is essential to the management of land resources.

Of equal importance are the oceans which supply much of the food for the people of the Pacific region. Trends of dwilling seafood supplies and declines in water quality have been evident for some time, (Australian Broadcasting Commisssion, 1990).

Pacific countries also face unique resource management problems due do the large distances between centres. These large distances are one of the major obstacles to the development of the region, (Australian Broadcasting Commission, op.cit.). Increasing populations caused by an increase in the growth rate and migration of people from outer islands to the major centres is also placing a strain on the resources of the region.

For these reasons it is important to map, monitor and plan the development of the regions terrestrial and marine resources.

Environmental and resource management decisions need to be based on reliable and comprehensive information. The isolated and widely spaced geographic distribution of the Pacific countries means that conventional methods of data collection are expensive and infrequent.

Data acquired from Remote Sensing (RS) platforms can provide repetitive, timely and accurate information about the earth and atmosphere at a variety of spatial and temporal resolutions (Table 1). Data collection alone is not enough however. Such data needs to be integrated and evaluated with other data sets so as to provide reliable decision making information.

Geographic Information Systems (GIS) provide a vehicle for the efficient handling for the large amounts of spatial information produced by image analysis systems. A GIS is an automated system designed to capture, store, retrieve, analyse and output all forms of geographically referenced data.

Once entered into a GIS, information can be modelled for a variety of purposes including land capability mapping, erosion modelling and test scenarios for environmental impact assessment. An added bonus of using a GIS is that other forms of data can be managed such as facilities and cadastral information.

The integrated use of remote sensing and geographical information systems is essential for efficient use of data. Each system can be used in isolation provide useful benefits. However, combined in their application they form a very powerful tool for resource management and planning.

The use of the Golbal Positioning System (GPS) in conjunction with RS and GIS adds a dimension of spatial accuracy to these data not possible or affordable using more traditional surveying methods.

RELATIONSHIP BETWEEN REMOTE SENSING GEOGRAPHIC INFORMATION SYSTEMS AND GLOBAL POSITIONING SYSTEMS

Remote sensing systems are primarily concerned with the acquisition of data which is then transformed into information via an image analysis system. GIS is primarily concerned with the management, analysis and modelling of spatially related information such as that derived from an image processing system. The marriage of these two technologies is therefore a logical step in the evolution of a Geographic Information Processing System (GIPS), a system which handles all aspects of data input and processing.

The current trend is for RS systems to provide data at increasingly finer spatial resolutions. Consequently there is a requirement for an increase in the spatial accuracy in the ground control used to rectify such data. To this end, the incorporation of GPS data to georeference both remotely sensed and GIS data is essential.

Figure 1 shows the relationship between RS, GIS and GPS as developed by the RMIT Centre for Remote Sensing, departement of Land Information at the Victoria University of Technology in Melbourne, Australia.

Remote sensing can benefit from ancillary data sets being incorporated in the image analysis process. For example the classification accuracy of areas of mangrove could be improved by incorporating digital elevation data. This thematic layer could then be entered into the GIS as a layer suitable for further analysis. This two way flow information is the fundamental principle which makes the merging of these technologies so successful.

GPS can be used to provide accurate and selectable ground control coordinates useful for the rectification of satellite imagery. Ground control points can be measured to sub-centimetre accuracy if required. Word undertaken at the RMIT Centre for Remote Sensing has shown a substantial increase in the rectification accuracy of LANDSAT TM data when using GPS control instead of 1:25 000 map coordinates. Table 2 shows some of the accuracy improvements achievable.

GPS is also useful for ground control of data input for a GIS. GPS can also be used to accurately locate features identified by satellite imagery and GIS analysis when in the field undertaking accuracy assessment.

Within the RMIT Centre for Remote Sensing the link between RS and GIS is provided through the ERDAS - ARC/INFO live link system. ERDAS is an image processing system and ARC/INFO is a GIS. The live link allows geographic referencing parameters to be passed between the two software programmes. GPS input is via TRIMBLE NAVIGATION 4 000 ST GPS receivers.

The integrated use of these three technologies is seen as central to the RMIT Centre for Remote Sensing in its mapping, monitoring and modelling programmes. The term Geographic Information Processing System (GIPS) has been adopted for this integrated approach.

THE ROLE OF A GIPS IN RESOURCE MANAGEMENT

The definition of "resource" in this paper is very broad and encompasses the land, the sea, the people, the air and the environment.

The role of a GIPS in the management of resources is given in figure 2.

If a resource is to be managed efficiently and effectively then a well defined management plan is required. This management plan is based on existing resources ; existing infrastructure, current and predicted requirements of the resources as well as environmental and political considerations.

Insular environments such as those in the Pacific region often lack the necessary surveys to adequately document the bio-physical resources of their territories. This problem is not restricted to the Pacific region. Few if any of the so called developed nations currently have adequate information on their bio-physical resources from which they can make sound resource management decisions. To this end a GIPS is useful in acquiring and storing base line data on the bio-physical resources and infrasturctures of an area.

Once base line data has been collected current resources can be analysed ans an appropriate management plan implemented.

Other data can then be collected and analysed with respect to the base line data set. For example, agricultural statistics could be compiled and compared to physical parameters such as soil type, slope, aspect, hydrology and so on. Using these simple modelling techniques a land capability survey could be conducted to ascertain the optimum land use for different land terrain units.

At this stage an evaluation and modification of the management plan might be appropriate.

Once established a geographic database, managed by a GIPS can be used to model and make recommendations on development applications over an area. Such applications may be deemed acceptable, in which case the GIPS can be used to remap the resources after the development and to monitor the effects of that development. Potentially harmful projects would hopefully be recognised before implementation and either be disallowed or returned to the applicant for modification so as to satisfy the requirements of the management plan.

CASE STUDY - GEOGRAPHIC DATABASE OVER THE ISLAND OF TONGATAPU

In order to demonstrate the application of a GIPS to the construction of a geographic database, the RMIT Centre for Remote Sensing, in conjunction with Riedel and Byrne Consulting Engineers, have undertaken a research project to construct a partial geographic database over the island of Tongatapu in the Kingdom of Tonga. Available data sets include :

1. 1973 1:25 000 topographic map over the island
2. 1988 SPOT XS imagery
3. 1990 SPOT Panchromatic imagery
4. Limited Black and White aerial photography (recent colour photography is now available)
5. Some local knowledge.

Colour figs. P18A and P18B show satellite imagery over the island.

In addition the following information would be desirable but as yet is unavailable.

1. Soils map
2. Geology map
3. Some batymetric data to calibrate satellite derived depths
4. Population statistics
5. Cadastral information
6. GPS derived ground control over the island

Aim

The principal aim of the project is to demonstrate the usefulness of a GIPS to the management of the Kingdom of Tonga.

The technologies used in this project are relatively inexpensive. It should therefore be possible to implement a methodology for technology transfer whereby local planners and managers of the region can be trained to implement their own databases given appropriate staff resources.

The database

The following layers have been entered into the GIS at a scale of 1:25 000.

1. Roads - Works has commenced on updating the road network using the high resolution satellite data (10 m ground resolution)
2. Contours - DEM
   - Slope
   - Aspect
3. Estates
4. Some facilities

Work currently underway includes

1. Bathymetric mapping of the surrounding waters
2. Water quality monitoring for Fanga'uta lagoon
3. Mangrove mapping using satellite data supported by aerial photography
4. Raster scanning of aerial photography into digital format for use in image analysis system
5. Land cover mapping.

Colour figs. P18C and P18D show some of the data layers entered into the GIPS.

The project has been hampered by several factors.

1. Lack of adequate ground control for rectification of satellite imagery
2. No external funding has been provided for the study
3. Workers on the project have no ground truth information on which to base their analysis.

Nevertheless the project has achieved some results and these are presented here.

UPDATING OF ROAD NETWORK

The 1990 SPOT satellite imagery with a spatial resolution of 10 metres was rectified using the 1:25 000 map. This image was only received a week ago.

The existing road network as digitised from the topographic map was then overlayed on the imagery. New roads not shown on the map were clearly visible and could be digitised from the screen using the capabilities of the GIPS (colour fig. P18E), note the new roads shown in purple). When completed a new road map can be produced using the cartographic output capabilities of the GIPS. Accurate ground control from GPS would allow more accurate road mapping to take place.

DERIVATION OF A DIGITAL ELEVATION MODEL

Once the contours were digitised into the system the GIPS can derive a digital elevation model (colour fig. P18F). Such a model can be used to derive slope and aspect. It is also useful to present information modelled in the GIS so that it can be assimilated within a topographic context. Colour fig. P18G shows a DEM of the region around Nuku'alofa and Fanga'uta lagoon. The coast and road network has been draped over this DEM to demonstrate this principle. When completed the mangrove mapping results could be presented in a similar way. The DEM can also be used to simulate sea level rises of various magnitudes and model the areas most under threat storm activity and inundation. Once completed the GIPS can also be used to create a 3 dimensional map of the coastal bathymetry.

CONCLUSIONS

The integrated use of remote sensing, geographic information systems and global positioning systems into a Geographic Information Processing System provides resource managers with a powerful tool to assist them in the efficient and effective execution of their duties.

This is particularly so in the Pacific region where geographical consideration make it difficult to monitor existing resources using more conventional approaches such as aerial photography.

The unique problem faced by the Pacific countries means that they have much to gain from the implementation of these technologies. More efficient management of existing resources taken within the context of current and future needs would mean easier, efficient and more rapid development.

The technologies used in this kind of project are relatively inexpensive and it should be possible for this programme to be extended such that Pacific nations themselves can create their own databases provided the appropriate personnel can be trained.

AKNOWLEDGEMENTS

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Table 1 Source of remotely sensed dada suitable for urban applications.

LANDSAT THEMATIC MAPPER	- 30 m - 16 days - 7 bands
FUTURE - 15 m PANCHROMATIC BAND - STEREO	
SPOT MULTISPECTRAL	- 20 m - 2 to 26 days - 3 bands - stereo
PANCHROMATIC	- 10 m - 2 to 26 days - 1 band - stereo
FUTURE - 5 m PANCHROMATIC BAND	
SOJUZKARTA - VARIETY OF SPACE PHOTOGRAPHY	- eg MK 4 - 6 m - 3 bands - stereo

Table 2 : Comparison of model accuracy between GPS derived ground control points and 1/25 000 map derived ground control points.

MODEL ORDER	ERROR X	ERROR Y	
AFFINE GPS	0.399	0.386	
AFFINE MAP	0.535	0.525	
QUADRATIC GPS	0.480	0.410	
QUADRATIC MAP	0.937	0.852	
CUBIC GPS	0.980	1.180	
CUBIC MAP	3.608	3.107	
GCP = GLOBAL POSITIONING SYSTEM DERIVED POINTS MAP = 1:25 000 DERIVED POINTS			

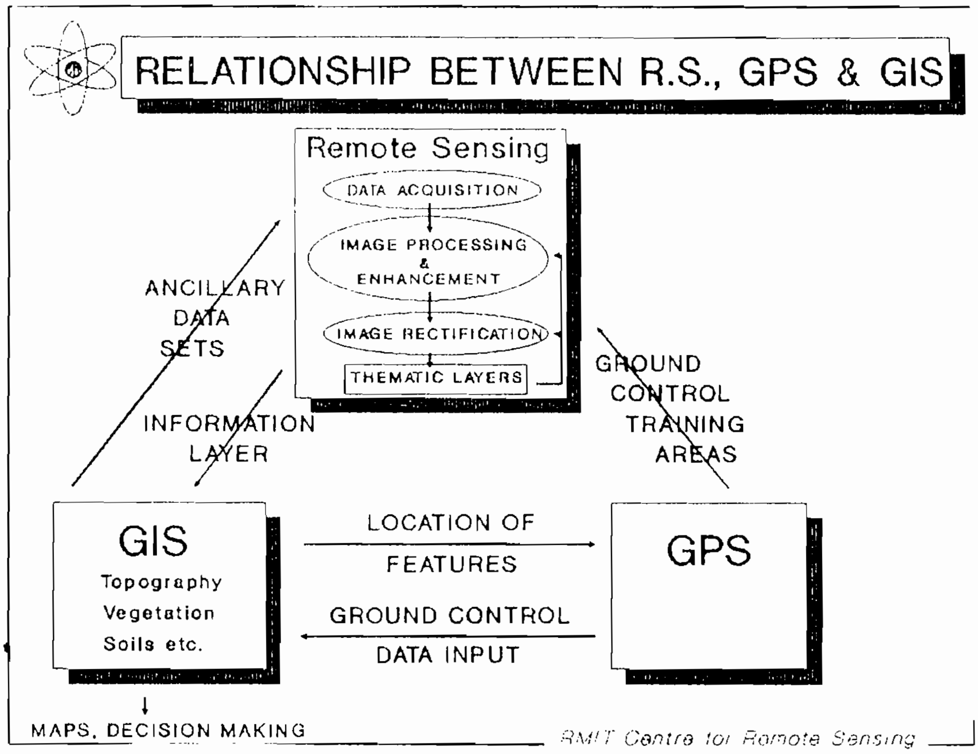


Figure 1 : Relationship between Remote Sensing Geographic Information Systems and Global Positioning Systems. The developement of a Geographic Information Processing System.

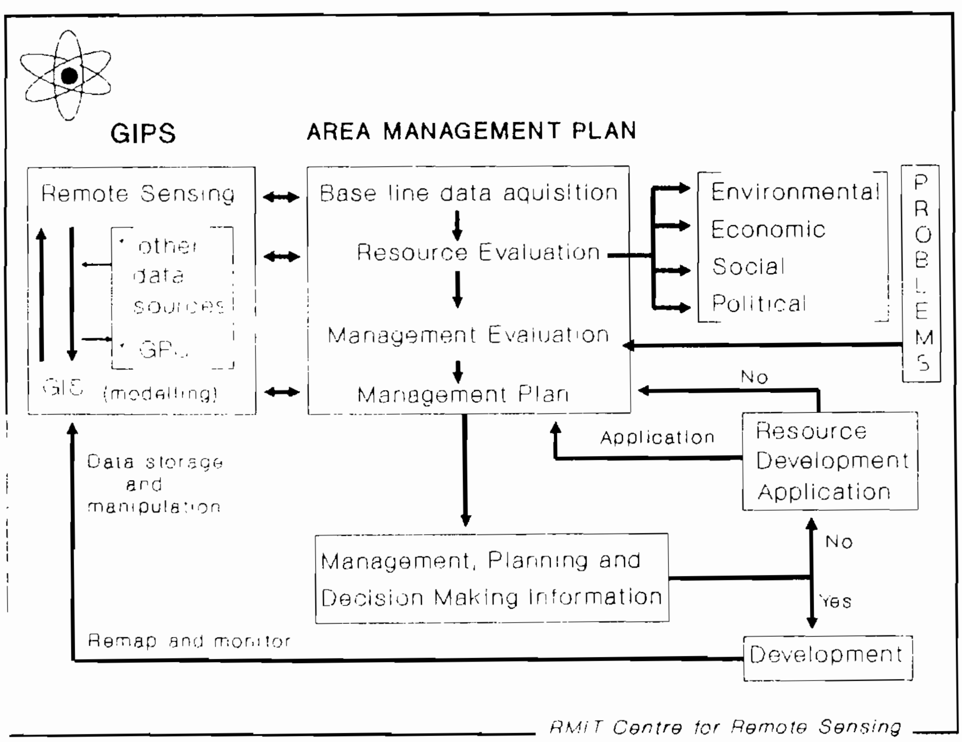


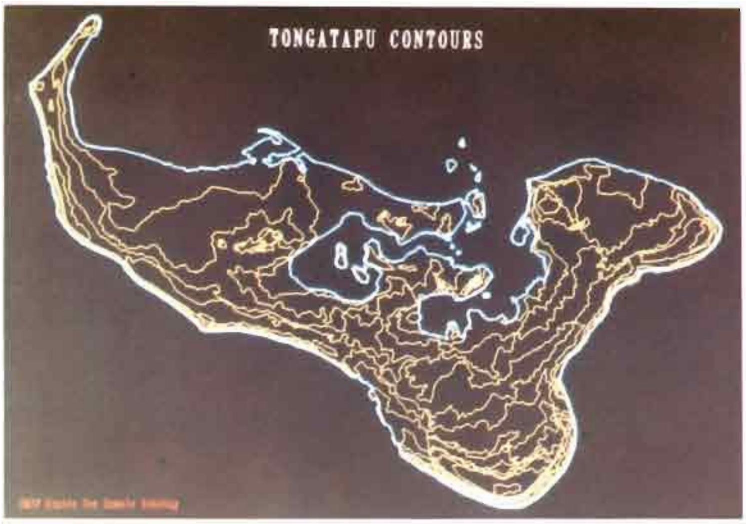
Figure 2 : Role of a Geographic Information Processing System in Resource Management.

P18

P18A : SPOT multispectral Image of Tongatapu acquired June 1988. C CNES 88/dist. SPOT IMAGE.

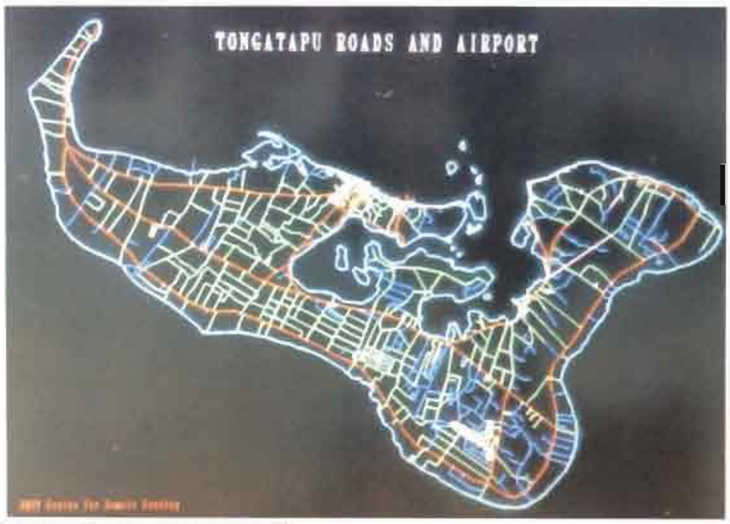
P18B : SPOT Panchromatic Image of Tongatapu acquired July 1990. C CNES 90/dist. SPOT IMAGE.

P18



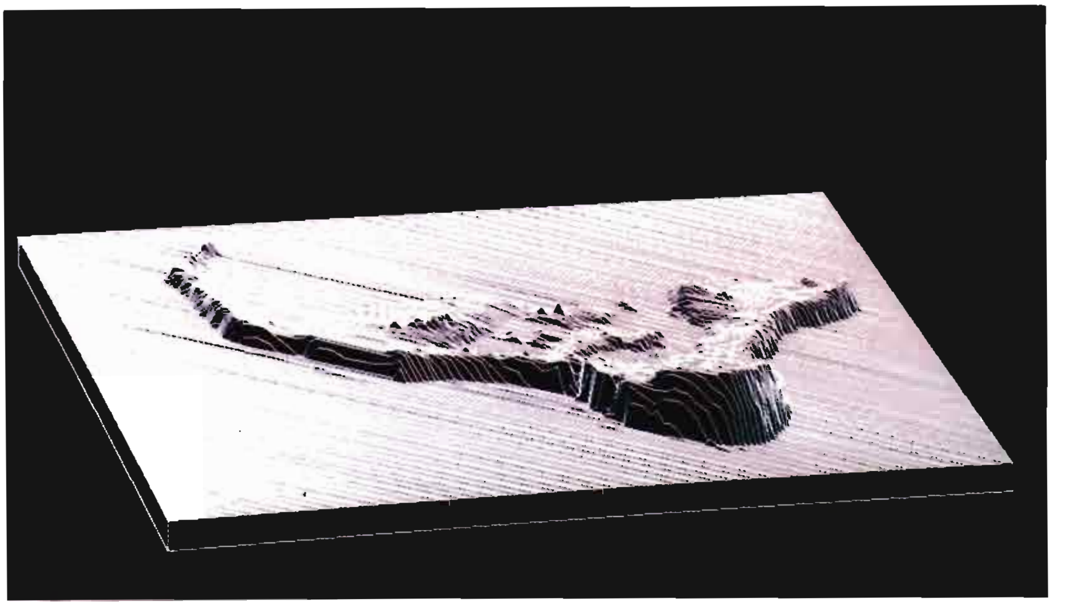
P18C : Contours.

P18D : Roads and Airport.

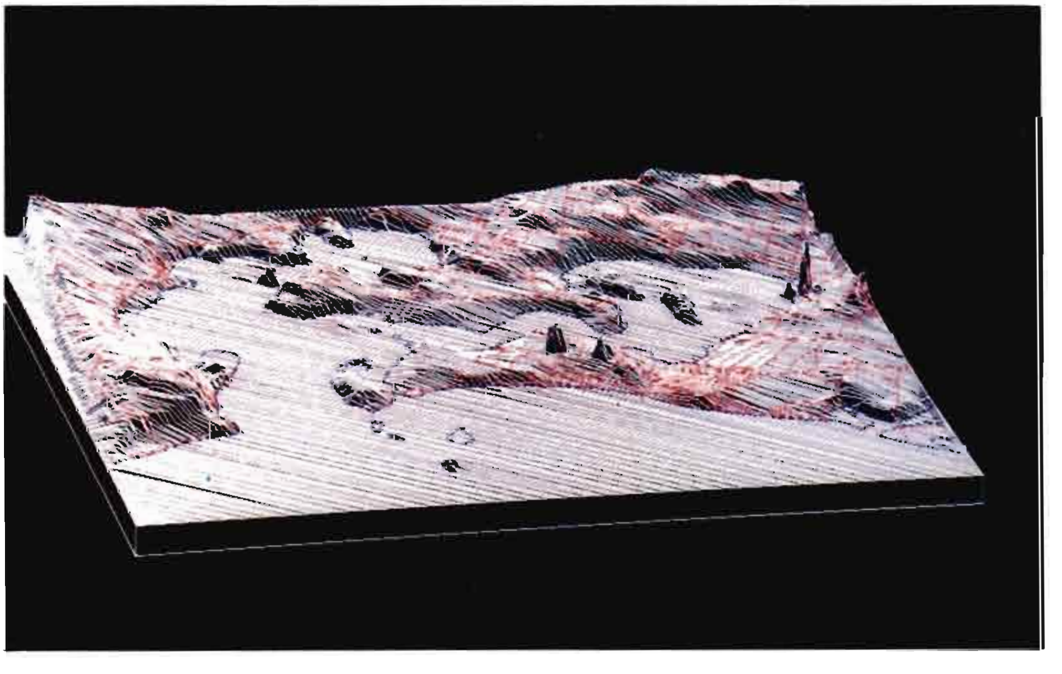


P18E

Roads over Panchromatic Image. Roads shown in purple have been updated from imagery.



P18F : Digital Elevation Model of Tongatapu. View looking to the North.



P18G : Digital Elevation Model of Nuku'Alofa and Fanga'uta Lagoon. View is looking towards the South.

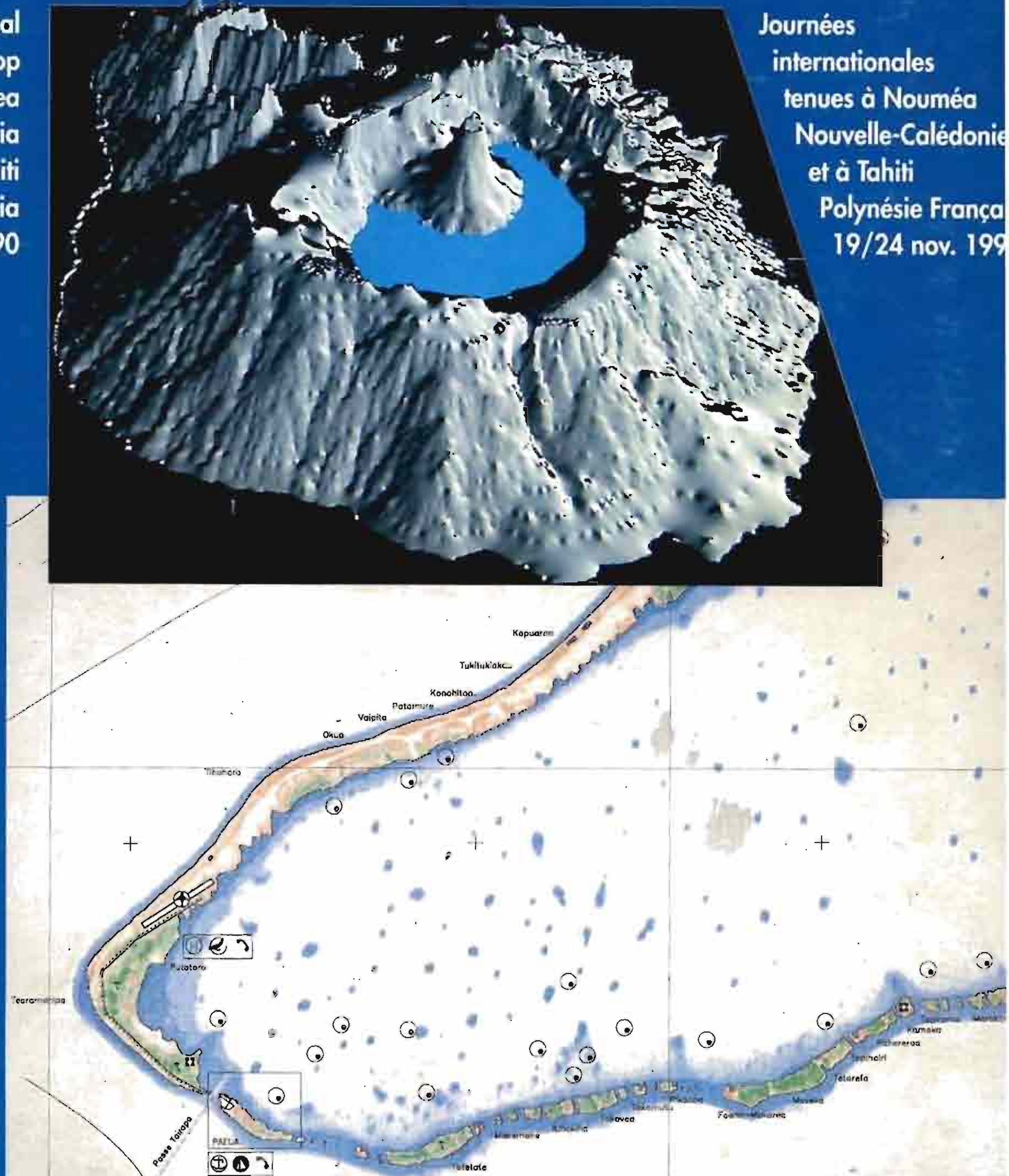
"PIX'ILES 90"

TELEDETECTION ET MILIEUX INSULAIRES DU PACIFIQUE : APPROCHES INTEGREES

REMOTE SENSING AND INSULAR ENVIRONMENTS IN THE PACIFIC : INTEGRATED APPROACHES

International workshop held at Noumea New Caledonia and Tahiti French Polynesia Nov. 19/24 1990

Journées internationales tenues à Nouméa Nouvelle-Calédonie et à Tahiti Polynésie Françai 19/24 nov. 199



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