

**INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION  
(of UNESCO)**



**SEA LEVEL MEASUREMENT AND ANALYSIS IN THE  
WESTERN INDIAN OCEAN**

**NATIONAL REPORTS**

**COMORES**

**FRENCH INDIAN OCEAN ISLANDS** (*Mayotte, Reunion, Crozet, Kerguelen, St. Paul*)

**SOMALIA**

JULY, 1999

## PREFACE

During the fourth session of the Intergovernmental Oceanographic Commission's Regional Committee for the Co-operative Investigations in the North and Central Western Indian Ocean (IOCINCWIO) held in Mombasa, Kenya in May 1997, a project proposal entitled "Sea Level data and Information in the IOCINCWIO region" was submitted and endorsed. Subsequently the Kenya Marine & Fisheries Research Institute (KMFRI) and the Institute of Marine Sciences of the University of Dar es Salaam, Tanzania prepared a detailed proposal which was approved for funding by IOC within the framework of the IOC-Sida-Flanders Marine Science programme.

The main objectives of the project are:

- Preparation of a comprehensive report on the tide gauges which have operated in the region, the volumes, quality of data collected
- Inventory of capacity available for installation, levelling and maintenance of gauges, as well as analysis of data
- Identifying the requirements for completion of the National, Regional and GLOSS network components in each of the countries of the region
- Collection and analysis of sea level data 1Tom the Region, with a view to identifying variability of sea level and long term trends at different places in the region.
- Production of bibliography of sea level literature 1Tom the region

National experts from Kenya, Madagascar, Mauritius, Mozambique, Seychelles, South Africa and Tanzania were contracted to prepare national reports for their respective countries as per specified format.

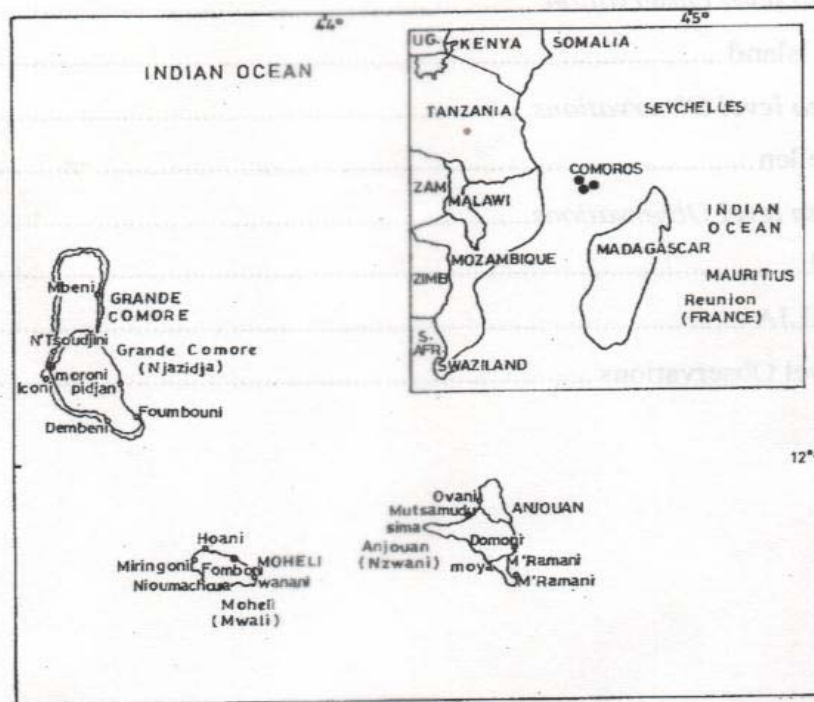
This report covers the other countries 1Tom the region: Comoros, French Indian Ocean Islands and Somalia and provides information on the geography and the status of the sea level network in each of the countries.

## CONTENTS

1.0	THE COMORES .....	1
1.1	Sea level Observations .....	2
2.0	FRENCH INDIAN OCEAN ISLANDS .....	2
2.1	Mayotte .....	3
	2.1.1 <i>Sea level Observations</i> .....	4
2.2	Reunion .....	4
	2.2.1 <i>Sea level Observation</i> .....	6
2.3	Crozet Island .....	7
	2.3.1 <i>Sea level Observations</i> .....	8
2.4	Kerguelen .....	8
	2.4.1 <i>Sea level Observations</i> .....	9
2.5	St Paul .....	9
3.0	SOMALIA .....	10
3.1	Sea level Observations .....	11

## 1.0 THE COMORES

The Comoros comprises three main islands: (Grand Comore, Moheli and Anjouan) and several islets located in the western Indian Ocean about ten to twelve degrees south of the Equator and less than 300km off the East African coast. They lie approximately half way between the island of Madagascar and northern Mozambique at the northern end of the Mozambique Channel. Mayotte, the fourth island in the archipelago is administered by France. The archipelago is the result of volcanic action along a fissure in the seabed running west-northwest to east-southeast.



*Figure 1: The Comoros Archipelago*

Grande Comore (also known as Ngazidja) is the largest island in the archipelago. It is the most westerly of the islands, lying 300km from Mozambique. It has an area of 1,146 square kilometers. The northern part of the island is dominated by a rocky plain known as La Grille, while to the south of the island there is an active volcano, Karthala, which stands over 2300meters high. Karthala's crater is nearly a mile in diameter, making it the largest active crater in the world. Since 1857 there have been over a dozen eruptions with lava flows. Agriculture on the island is generally limited to areas lower than 600metres in altitude. Above this altitude is the remnants of a dense tropical forest (in the south) and an area of grassy plain (in the center and north).

Moheli (also known as Mwali) is about 45km south-southeast of Ngazidja, is the smallest of the islands, with an area of 200 square kilometers and a central mountain range that rises 800 meters above sea level. The island has rich soil and produces coconuts, coffee, cacao and ylang-ylang and a wide variety of other crops.

Anjouan (also known as Nzwani) lies about 40km easterly of Mwali, with an area of 424 square kilometers and a central peak (Mount Ntingi) that rises 1,575 meters above sea level. It also has several swift running streams that cascade down to long, sandy beaches. Anjouan is the premiere producer of essential oils including ylang-ylang, jasmine, cassis, basilic, palmarosa, and orange flower.

### 1.1 Sea level Observations

There is no sea level station on any of the three islands of The Comoros. During the regional workshop on "Causes and Consequences of Sea level Changes on the Western Indian Ocean Coasts and Islands" held in Mombasa in 1991, Moroni was proposed as a possible site for a sea level station.

## 2.0 FRENCH INDIAN OCEAN ISLANDS

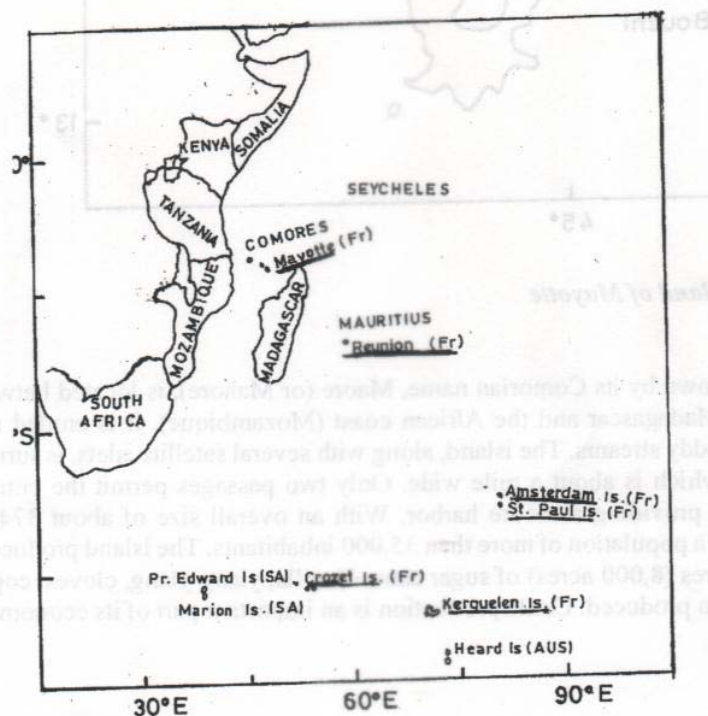
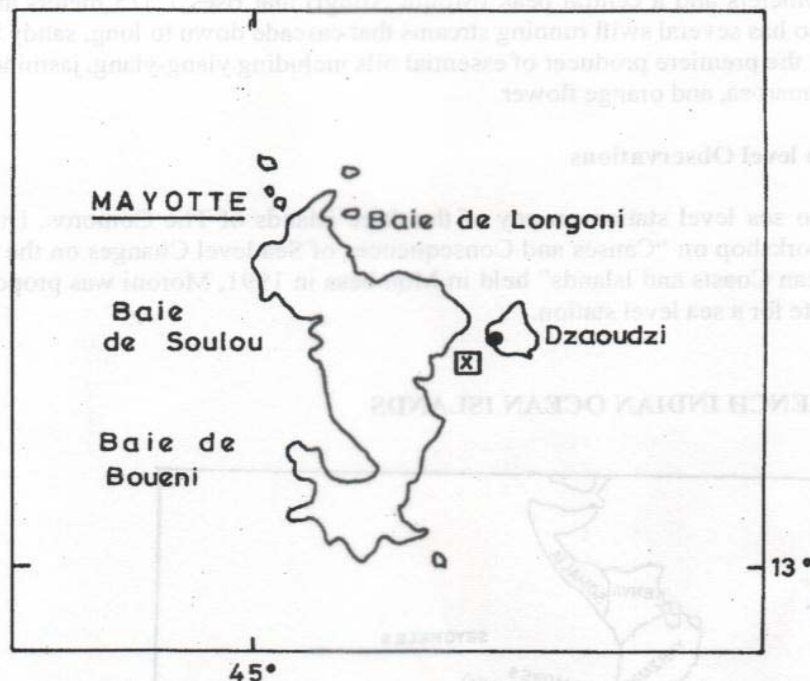


Figure 2: The French Indian Ocean Islands with sea level stations

There are six French administered islands in the Western Indian ocean which have or have had sea level stations. These are Mayotte, Reunion, Amsterdam-St. Paul, Crozet, and Kerguelen.

## 2.1 Mayotte



*Figure 3: The Island of Mayotte*

Mayotte, also known by its Comorian name, Maore (or Mahore), is located between the northern tip of Madagascar and the African coast (Mozambique). It is eroded and has slow moving, muddy streams. The island, along with several satellite islets, is surrounded by a coral reef which is about a mile wide. Only two passages permit the entrance of large ships, thus providing a secure harbor. With an overall size of about 374 square kilometers, it has a population of more than 35,000 inhabitants. The island produces more than 3,000 hectares (8,000 acres) of sugar cane. Vanilla, ylang-ylang, cloves, copra, and cinnamon are also produced. Cattle production is an important part of its economy.

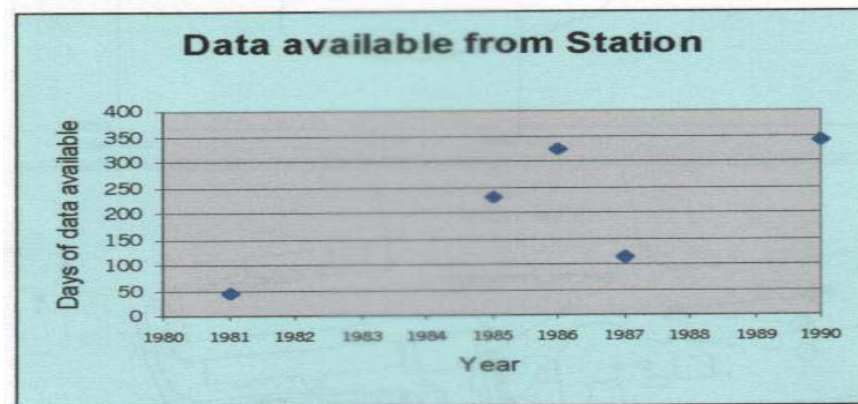
### 2.1.1 Sea level Observations

An OTTR16 was installed at Dzaoudzi (GLOSS station number 96) on 5 May 1985. The station is located at 120 46.80'S, 0450 15.3'E and was operational till December 1995. In its last years of operation, the tide well was regularly blocked, and digitization of the data was difficult due to a significant time drift coupled with insufficient calibration data. The last levelling of benchmarks was done in 1985.

There are no immediate plan to install another

The organisation responsible for operation and maintenance of the station is:

ODE de Mayotte  
BP69  
97610 Dzaoudzi



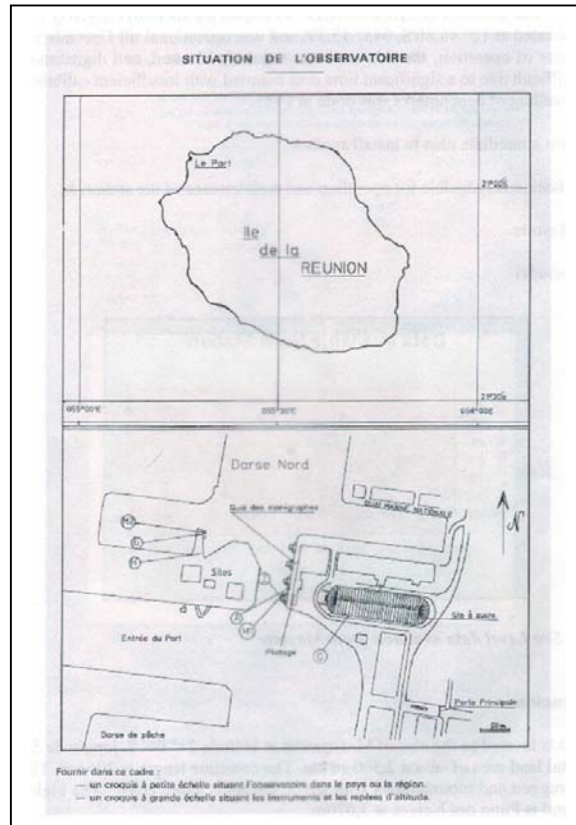
*Figure 4: Sea Level data available from Mayotte*

## 2.2 Reunion

The island is located to the east of Madagascar at latitude 21° 06' S, longitude 55° 36' E. It has a total land area of about 2,500 sq km. the coastline length is 200km. The terrain is mostly rugged and mountainous with fertile lowlands along coast. The highest point on the island is Piton des Neiges at 3,070m.

The climate is tropical, but temperature moderates with elevation. It is cool and dry from May to November, and hot and rainy from November to April. The island experiences periodic, devastating cyclones (December to April). Piton de la Fournaise on the southeastern coast is an active volcano.

The economy has traditionally been based on agriculture. Sugarcane has been the primary crop for more than a century, and in some years it accounts for 85% of exports.



**Figure 5: The island of Reunion showing a) location of sea level station (top), and b) location of tide gauge benchmarks (bottom)**



### 2.2.1 Sea level Observation

An OTTR16 was installed at Le Port- Pointe des Galets (lat: 20° 55.7', Long: 055° 17.9'E) on 29 April 1979 and operated till November 1986. The last levelling of benchmarks was done in 1985, while a GPS survey was done in 1993.

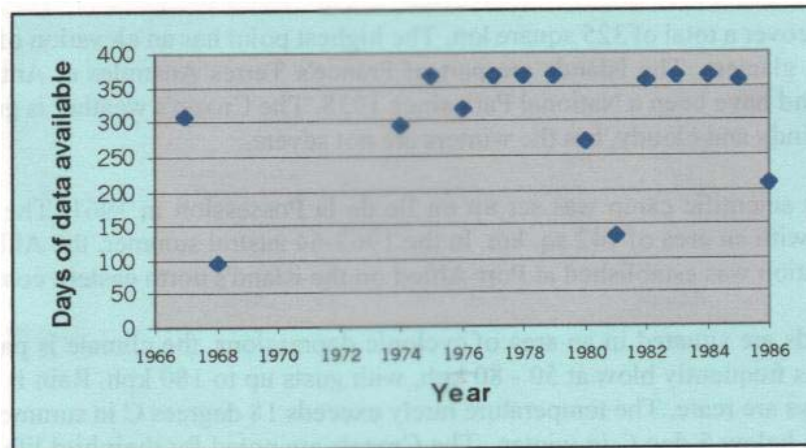
Another gauge installed in January 1993?

The station is operated and maintained by:

Sub division Entrein et Dragges  
Direction Departementale de l'Equipment de La- Reunion 2  
rue Evariste de Parly  
BP 2002  
97821 Le Port cedex

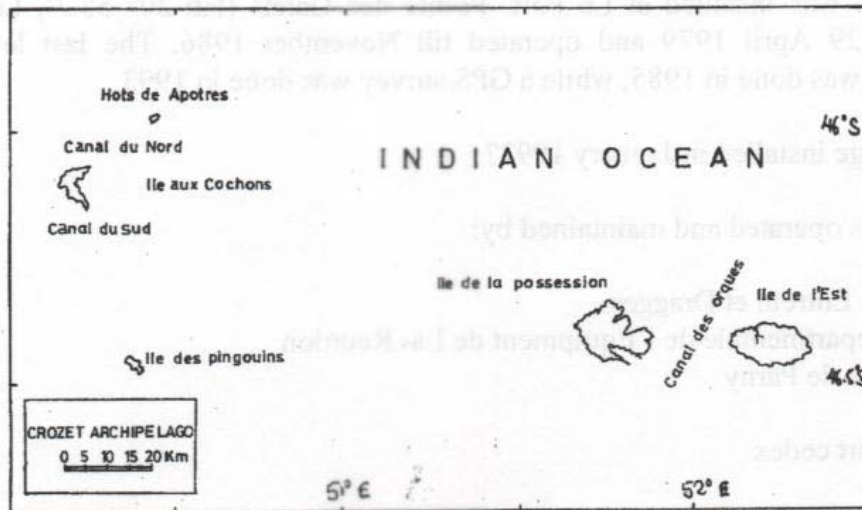
The data is processed and archived by:

Sub division Entrein et Dragges  
Direction Departementale de l'Equipment de La- Reunion 2  
rue Evariste de Parly  
BP 2002  
97821 Le Port cedex



*Figure 6: Sea data available from Reunion*

## 2.3 Crozet Island



*Figure 7: The Crozet Archipelago*

Les îles Crozet ( $45^{\circ}95'$  to  $46^{\circ} 50'S$ ,  $50^{\circ}33'$  to  $52^{\circ}58'E$ ) are divided into two groups, L'Occidental (île aux Cochons, îlots des Apotres, île des Pingouins and the reefs Brisants de l'Heroiné) and L' Oriental (île de l'Est and île de la Possession, the largest of the Crozets), about 100 km east. All the islands are volcanic in structure.

The islands cover a total of 325 square km. The highest point has an elevation of 1,090m; there are no glaciers. The islands are part of France's Terres Australes et Antarctiques Françaises and have been a National Park since 1938. The Crozet's weather is generally cold, wet, windy and cloudy, but the winters are not severe.

A temporary scientific camp was set up on île de la Possession in 1961. The island is 170m high, with an area of 142 sq. km. In the 1963-64 austral summer, the Alfred Faure scientific station was established at Port-Alfred on the island's north eastern coast.

As the islands are situated in an area of cyclonic depressions, the climate is particularly windy: winds frequently blow at 50 - 80 kph, with gusts up to 180 kph. Rain is frequent, and clear days are rare. The temperature rarely exceeds 18 degrees C in summer, though it rarely falls below 5 deg C in winter. The Crozets are noted for their bird life, and half of the world's king penguins breed here.

### 2.3.1 Sea level Observations

A pressure sensor was installed at Crozet (GLOSS station number 21) since December 1994 as part of the ROSAME: Réseau d'Observation Subantarctique et Antarctique du Niveau de la Mer. These are equipped with water level pressure, sea water temperature, and atmospheric pressure. The station is automatic and transmits data through ARGAS. The hourly data, after validation are transmitted to the UHSLC.

The institution responsible for the station is INSU-IFRTP  
The station was operational from November 1995 to February 1997, and again from December 1998. GPS campaigns were undertaken in 1992, 1994 and 1995.

## 2.4 Kerguelen

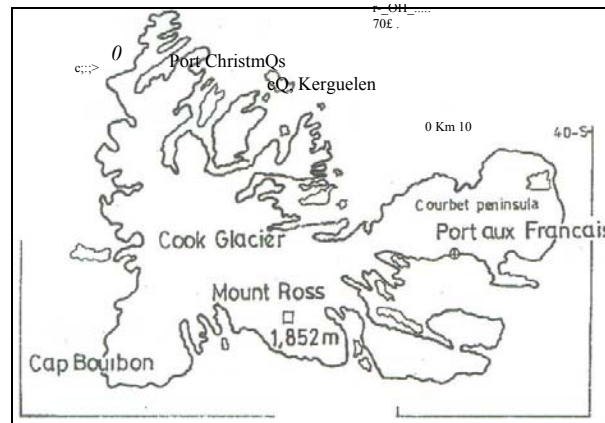


Figure 8: The Kerguelen Islands

The main island of Kerguelen (some 6,675 km<sup>2</sup>), is surrounded by 85 other islands, making an archipelago totalling 7,215 km<sup>2</sup>.

Kerguelen is situated at 49°20' South, 70°20' East, midway between Africa, Antarctica and Australia, and lies on the Antarctic Convergence where cold water from the Antarctic mixes with the warmer waters of the Indian Ocean. It is a paradise for birdlife and marine mammals, but has a poor flora, the only plant of note being the Kerguelen Cabbage.

Its mountains attain altitudes of 1,850m. One of them is an active volcano, and the whole of Kerguelen has been subjected in recent times to much volcanic activity, lava having covered much of its surface. This eruption of plutonic forces seems to have followed a severe glacial period, during which the island was covered with ice.

The climate of Kerguelen is uniform, with few extremes of temperature. Summer temperatures average 8°, whilst during the rest of the year temperatures average 1 - 2°. However, these temperatures mask the fact that the wind blows continually, bringing with it a chill factor and cloud. There are only 125 days of sunshine per annum.

The "Furious Fifties" blow more or less continually from the west, bringing permanent depressions. The most severe winds come out of the North West, and have attained speeds of 150 kph, gusting up to 200 kph. The record gust was recorded in August 1970 at 288 kph. Winds exceed 60 kph on 300 days per annum, with 140 days per annum having speeds exceeding 90 kph.

The state of the sea reflects these high wind speeds, with wave heights of 12 - 15 m being common. The sea around Kerguelen is, however, ice free.

Since 1950, Kerguelen has been part of the Terres Antarctiques et Australes Françaises (French Southern and Antarctic Territories) and with the explosion of scientific work in Antarctica and the Southern Ocean, has been continually occupied since then. Inhabitants have generally lived at Port aux Français. The population consists of geologists, geophysicists, meteorologists, oceanographers, ornithologists and biologists, and oscillates between 50 in the winter to as many as 100 in the summer.

CNES (The French National Space Centre) operates a base at Port aux Français dedicated to the tracking of satellites.

#### 2.4.1 *Sea level Observations*

A pressure sensor has been in operation at Kerguelen (GLOSS station number 23) since April 1993 as part of the ROSAME: Réseau d'Observation Subantarctique et Antarctique du Niveau de la Mer. These are equipped with water level pressure, sea water temperature, and atmospheric pressure. The station is automatic and transmits data through ARGOS. The hourly data, after validation are transmitted to the UHSLC. GPS campaigns have been carried out in 1992, 1994, and 1998. There are also permanent DORIS and GPS stations

The institution responsible for the station is INSU-IFRTP

## 2.5 **St Paul**

A pressure sensor has been in operation at Amsterdam- St Paul (GLOSS station number 24) since October 1994 as part of the ROSAME: Réseau d'Observation Subantarctique et Antarctique du Niveau de la Mer. These are equipped with water level pressure, sea water temperature, and atmospheric pressure. The station is automatic and transmits data through ARGOS. The hourly data, after validation are transmitted to the UHSLC.

The institution responsible for the station is INSU-IFRTP

### 3.0 SOMALIA

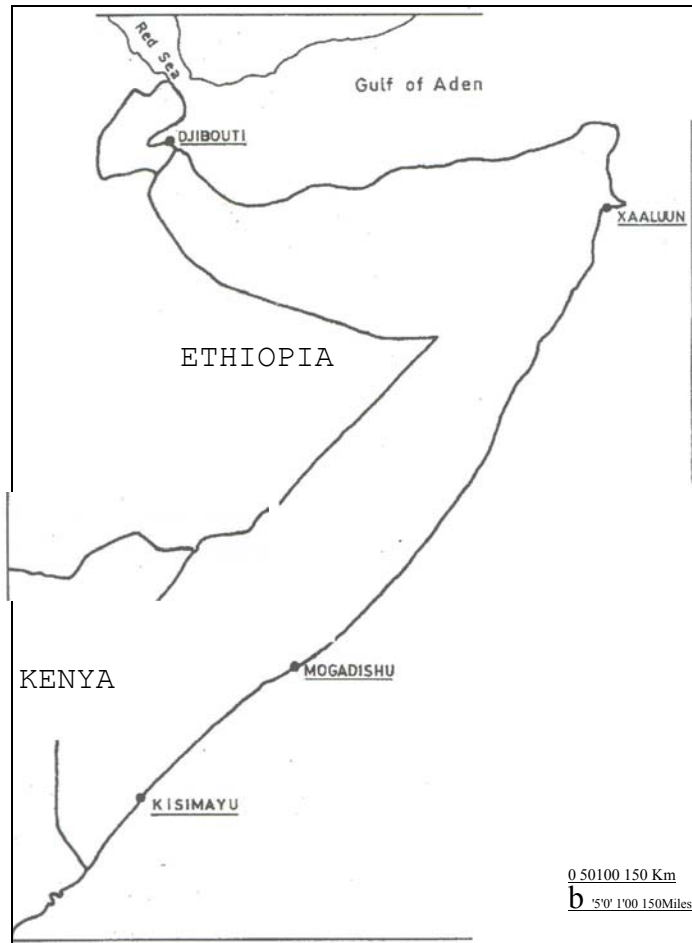


Figure 9: The coasts of Somalia and Djibouti, showing proposed GLOSS stations

Somalia is situated in the eastern tip of Africa. The total area is 637,660 sq km. . Somalia has the longest coastline of the East African countries of 3300 km of coastline, of which 2000 km fringe the Indian Ocean and the remaining 1300 km of the northern part of the country facing the Gulf of Aden, extending from Raas Casey to the border with Djibouti. Somalia has the second longest marine littoral and an Exclusive Economic Zone being almost 1.2 million km<sup>2</sup>. The continental shelf throughout most of its length is narrow varying from 5 to 15 km except for a stretch extending approximately for 135 km in the north east where the width average is 70 km.

Most of the coastline consists of a series of sandy beaches and bays interrupted in places by rocky cliffs and headlands. The southern coast of the Gulf of Aden consists of a series of sandy bays interrupted by rocky promontories extending into sea down to a shallow depth. There are neither fringing reefs nor bars. Between 6° and 8° N, the coast becomes sandy with gradual appearance of coral.

The climate is arid with an average annual rainfall of less than 300 mm. Seasonal variation is mainly influenced by the monsoon winds, which also determine the coastal currents. From May to August, the south-west monsoon drives a strong current from the level of Socotra to the east. From October to March, during the north-east monsoon, waters flow from the Arabian Sea into the Gulf of Aden. The Somali Current forms the equatorial counter currents and due to less turbulence, a thermocline develops at about 60-80 m depth, with surface waters having uniform temperatures between 28-30 °C and a salinity of about 34.5 parts per thousands. During the south-west monsoon, the Somali Current transports about 50-65 million m<sup>3</sup>/sec. of water penetrating deep into the oceanic water mass and causing upwellings of cold water in the north-east. These upwellings induce high productivity off the Somali coast as the turbulent activity brings nutrient rich cold sub-surface waters with temperatures below 200 °C to the surface. The average temperature of the surface water is 24 °C with a salinity of 25 parts per thousands.

In May, 1991, former British Somali land declared itself independent and a government was installed, but the "Republic of Somalia" is not recognised internationally. The situation in the southern part of the country is more complex and volatile with a wide range of political and armed : fractions that are still fighting for control.

Throughout Somalia animal husbandry and agriculture are the main economic activities. Despite rich marine and coastal resources, which could make a significant contribution to the economic development of the country, they account for a small percentage of GDP.

### **3.1 Sea level Observations**

There is no operational sea level stations in Somalia. Two GLOSS stations were planned for Somalia: Hafun (GLOSS station no. 6) and Mogadishu (GLOSS station no. 7). The University of Hawaii installed a Fisher and Porter (float type) tide gauge in Mogadishu in 1988. A Leopold Stevens float gauge was installed at Kismayu in 1988. No data from these gauges was submitted to any of the international data centres.

The organisation which was operating both gauges was:

Somali Ports Authority  
P.O. Box 935  
Mogadishu, Somalia.

It is unlikely that the organisation still exists in the same form.