DISTRIBUTION OF LONGSHORE SEDIMENT TRANSPORT ALONG THE INDIAN COAST BASED ON EMPIRICAL MODEL

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ABSTRACT

An empirical sediment transport model has been developed based on longshore energy flux equation. Study indicates that annual gross sediment transport rate is high (1.5 x 10^6 m^3 to 2.0 x 10^6 m^3) along the coasts of south Orissa, north Tamilnadu, south Kerala, north Karnataka and south Gujarat, whereas it is comparitively less (0.5 x 10^6 m^3 to 1.0 x 10^6 m^3) along the south Tamilnadu coast. Coast between Pondicherry and Point calimere in Tamilnadu, and Maharashtra coast experience negligible quality of annual net transport. The direction of annual net transport along the east coast is in north and along the west coast in south except at south Gujarat coast.

INTRODUCTION

India has a long coastline of over 6000 km along the main land, in addition to that of the Andaman and Nicobar islands in the Bay of Bengal, and the Lakshadweep in the Arabian Sea. The morphology of the Indian coast is quite complex, with long sandy beaches and high dunes along the low-lying east coast, and with many pocket beaches and headlands along the west coast. Coast along the West Bengal is characterised by shoals and spits, whereas, Orissa, AndraPradesh and Tamilnadu is marked by long sandy beaches with high and wide backshore. Sandy beaches appear in Trivandrum and from Cochin to Calicut. Low cliffs, pocket beaches and bays are found from Calicut to Mangalore. Karnataka and Maharashtra coasts are marked by creeks, headlands and barriers. Goa has long and beautiful beaches. Rocky shores with intermittent sandy beaches are found along the south Gujarat coast. Gulf of Kutch is dominated by deep inlets offshore islands and marshes. Rann of Katchchh gets flooded during the southwest monsoon and becomes dry and barren during the rest of the year. For the coastal developments in general, port and harbour development and control of beach erosion in particular, the thorough understanding of the littoral environment is very essential. The entire stretch of the Indian coast, from New Moore Island in the east to Jakhau in the west, has been considered in the present study for estimating the longshore sediment transport rate.

WAVE DATA

India Meteorological Department publishes weather data transmitted by the ships plying in the Indian waters in the form of Indian Daily Weather Reports (5). Since, the directional information are not appended for sea waves in these reports, only the swell data reported for the period 1968 to 1986 are considered for the present study. Indian coastal region is divided into 8 grids each of 5^o x 5^o size and the swell data pertaining to each grid are compiled (Fig. 1). Ship reported wave heights are considered to be equal to the deep water significant wave height (H_s) and the visually measured wave periods as the zero crossing wave periods (T_z) (4).

LONGSHORE SEDIMENT TRANSPORT EQUATION

Longshore sediment transport rate is generally estimated from an empirical equation relating the longshore energy flux in the breaker zone to the longshore transport rate (3), (8). Based on the shore protction Manual (6), the deep water version of the longshore transport equation is related to the longshore component of the wave energy flux as,

$$Q = 1288 \frac{\rho g^2}{64\pi} T (Ho.Kr)^2 \sin 2\alpha_b \qquad (1)$$

where Q = volume rate of longshore transport in m^3/yr, g = acceleration due to gravity in m/s^2, T = wave period in s, is the breaker angle and H_o is the deep water wave height and Kr is the refraction coefficient.

By incorporating the effect of wave shoaling the bottom friction eqn. (1) can be rewritten as,

$$Q = 1288 \frac{\rho g^2}{64\pi} T (Ho.Kr.Ks.Kf)^2 \sin 2\alpha_b \qquad (2)$$

where, Ks and Kf are the shoaling and bottom friction coefficients.

As the data compiled for the present study correspond to deep water condition, eqn. (2) is used for estimating the longshore sediment transport rate. The procedure adopted in Skovgaard, Jonsson and Bertelsen (7) is followed to compute the shoaling, refraction and bottom friction coefficients and method of estimation are explained in Chandramohan (1).

EMPIRICAL SEDIMENT TRANSPORT MODEL

When the coast is assumed as long and open sandy beach with adequate supply of sand, the monthy longshore transport rate is obtained by,

$$Q_m = \frac{1}{12} \sum_{H=0}^{H=\infty} \sum_{T=0}^{T=\infty} \sum_{\beta=\alpha}^{\beta=\alpha+\pi} Q.f_m (H, T, \beta) \qquad (3)$$

Where, Q = Annual volume rate of longshore transport transport from eqn. (2)

Q = Monthly volume rate of longshore transport

f_m (H,T,β) = frequency of occurrence of particular set of (H,T,β) in a month.

β = azimuth of the coastline

α = azimuth of the wave direction

Using eqn. (3), the longshore sediment transport for every 10^o variation of the coastline orientation in each grid is estimated.

RESULTS AND DISCUSSION

The segment of the coastline bounded by each grids are: grid 1 from New Moore Island to Paradeep, grid 2 from Chandrabhaha to Ganjam, grid 3 from Gopalpur to Ramaypatnam, grid 4 from Allur to Athirampatnam, grid 5 Manamelkudi to Cochin, grid 6 from Ponnani to Karwar, grid 7 from Goa to Tarapur and grid 8 from Umbergaon to Jakhau.

The annual gross and net transport rates were estimated for every 10^o variation of coastline in each grid, and the results are presented as rose diagrams in Fig. 2. Using these rose diagrams, the annual transport rate can be read for the desired location along the Indian coastline. The procedure for reading the rose diagrams are: i) angle of inclination of the coastline with respect to north in clockwise direction has to be measured either at field or from maps, ii) identify the grid in which the coastline falls, iii) refering the corresponding rose diagrams, the longshore sediment transport rate can be read for the known orientation of the coastline, and iv) linear interpolation is used for the coastal segment with intermediate angle (1), (2). The transport rates at selected locations along the Indian coast are presented in Table 1. Chandramohan (1) has discussed in detail the validation of the model and comparision of the results with earlier studies along the Indian coast.

In grid 1, the direction of transport is towards northeast from February to November and southwest in December and January. Shorelines oriented about 80^o with north are subjected to maximum transport, with a gross volume of 2.10 x 10^6 m^3 and a net volume of 1.4 x 10^6 m^3 per year. The direction of annual net sediment transport is towards northeast.

In grid 2, the transport is northeasterly from March to October and southwesterly from November to February. Coasts with inclination of 80^o to north undergo transport of sediment with a gross volume of 1.87 x 10^6 m^3 and a net volume of 1.56 x 10^6 m^3 per year. The average orientation of this coastline is 40^o with annual gross and net longshore transport of 1.26 x 10^6 m^3 and 0.74 x 10^6 m^3 respectively. The direction of annual net transport is northeasterly.

In grid 3, the transport is northeasterly from March to October and southwesterly during the rest of the year. Coasts oriented at 80^o to north are subjected to highest transport with a gross volume of 1.53 x 10^6 m^3 and a net volume of 1.09 x 10^6 m^3 per year. Average orientation of the coastline in this grid is around 50^o and the annual gross and net longshore transport rates are 1.23 x 10^6 m^3 and 0.70 x 10^6 m^3 respectively. The direction of annual net transport is northeasterly.

In grid 4, the transport is northerly from April to October and southerly from November and March. Coasts having inclination of 40^o to north undergo maximum transport with a gross volume of 1.94 x 10^6 m^3 and a net volume of 0.91 x 10^6 m^3 per year. The annual gross and net transport, north of Pondicherry are about 1.79 x 10^6 m^3 and 0.44 x 10^6 m^3 respectively and south of Pondicherry till Point Calimere, 1.25 x 10^6 m^3 and 0.06 x 10^6 m^3 respectively. The annaul net transport is northerly between Pondicherry and Allur and southerly from Point Calimere to Chidambaram.

The coastal segment in grid 5, is exposed to high wave energy environment compared to the other part of the Indian coast due to its better exposure to the Indian Ocean. Between Manalmelgudi and Kanyakumari, the direction of transport is northerly from March to December and southerly in January and February. Coasts having the inclination of 90^o to north undergo maximum transport with a gross volume of 1.11 x 10^6 m^3 and a net volume of 0.59 x 10^6 m^3 per year.

The transport between Kanyakumari and Trivandrum is southerly from May to December and northely from January to April. Between Trivandrum and Cochin, the transport is southerly from January to March and June to September, and northerly in April, May and from October to December. Coasts having an orientation of 130^o to north undergo maximum transport of sediment in a year with a gross transport of 2.27 x 10^6 m^3 and a net transport of 1.09 x 10^6 m^3 whereas orientation of 160^o experience less transport with a gross volume of 1.86 x 10^6 m^3 and a net volume of 0.55 x 10^6 m^3 per year.

In grid 6, the transport is southerly from February to September and is nearly equal on either directions from October to January. Coasts having inclination of 130^o to north undergo maximum annual sediment transport with a gross volume of 1.94 x 10^6 m^3 and a net volume of 1.28 x 10^6 m^3. The average orientation of the coastline is about 150^o and the annual gross and net transport rates are 1.6 x 10^6 m^3 and 1.1 x 10^6 m^3 respectively. The annual net transport is southerly.

In grid 7, the direction of longshore transport during southwest monsoon is northerly, and southerly during the rest of the year. Coasts having inclination 130^o to north undergo maximum transport rate with a gross volume of 1.69 x 10^6 m^3 per year and a net volume of 1.34 x 10^6 m^3 per year. The average orientation of this coastline is around 170^o and the annual gross and net transport rates are 1.46 x 10^6 m^3 and 0.72 x 10^6 m^3 respectively.

In grid 8, the sediment transport between Umbergaon and Surat is southerly from November to April, and northerly during the rest of the year. Coasts having the inclination of 200^o to north are subjected to maximum transport with a gross volume of 1.69 x 10^6 m^3 and a net volume of 1.38 x 10^6 m^3 per year. The average orientation of this coastal stretch is around 180^o and the annual gross and net transport are 1.84 x 10^6 m^3 and 1.01 x 10^6 m^3 respectively In between Mahuva and Jakhau, transport is easterly through out the year except in November. Large transport of about 2.3 x 10^6 m^3 per month occurs during the southwest monsoon. The average orientation of the coast along this stretch is around 130^o and the annual gross and net longshore transport rates are estimated to be 1.55 x 10^6 m^3 and 1.10 x 10^6 m^3 per year respectively.

DISTRIBUTION AROUND THE INDIAN COAST

The general distribution of monthly longshore sediment transport rate along the Indian coast is shown in Fig.3. The annual gross and net transport rates are shown in Fig. 4.

The study shows that along the east coast, the longshore transport is southerly from November to February, northerly from April to September and variable in March and October. Along the west coast, the longshore transport is generally towards the south from January to May and in October. It is variable during other months showing northerly drift along the Maharashtra and south Gujarat coasts and southerly along the Karnataka and Kerala coasts from June to September. This phenomenon gets reversed in November and December.

Annual gross sediment transport rate is high (1.5 x 10^6 m^3 to 2.0 x 10^6 m^3) along the coasts of south Orissa, north Tamilnadu, south Kerala, north Karnataka and south Gujarat, whereas it is comparitively less (0.5 x 10^6 m^3) along the south Tamilnadu and Maharashtra coasts. The annual net transpot is northerly on the east coast and southerly on the west coast except along south Gujarat coast.

CONCLUSIONS

The present study on longshore sediment transport is based on longshore energy flux equation and the results are subjected to the assumption that the coast consists of a long open beach with adequate supply of sand. Through the results are reasonably applicable for the east coast, it has inherent limitation for the west coast, where numerous headlands and estuaries are intersecting the littoral zone. Study shows annual gross sediment transport rate is high (1.5 x 10^6 m^3 to 2.0 x 10^6 m^3) along the coasts of south Orissa, north Tamilnadu, south Kerala, north Karnataka and south Gujarat whereas it is comparitively less (0.5 x 10^6 m^3 to 1.0 x 10^6 m^3) along the south Tamilnadu coast. Coast between Pondicherry and Point Calimere in Tamilnadu and Maharashtra coast experience negligible quantity of annual net transport. The annual net transport at the southern most tip of Indian Peninsula (Kanyakumari East Cape) is negligible. The annual net transport along the east coast is northerly and along the west coast it is southerly except on the south Gujarat coast.

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Table 1. Longshore transport rate at important places in 10^6 m^3/yr.

Locations		
EASTCOAST:	Southerly	Northerly
Dariapur	0.273	- 1.528
Paradeep	0.284	- 1.625
Gopalpur	0.260	- 0.962
Visakhapatnam	0.318	- 0.845
Kakinada	0.262	- 0.960
Machilipatnam	0.502	- 0.440
Krishnapatnam	0.698	- 0.895
Madras	0.683	- 1.027
Pondicherry	0.692	- 0.939
Cuddalore	0.698	- 0.895
Karaikal	0.660	- 0.656
Manamelkudi	0.490	- 1.432
Tuticorin	0.330	- 0.330
Kanyakumari(east)	0.312	- 0.398
Kanyakumari(tip)	0.336	- 1.086
WESTCOAST :	Northerly	Southerly
Trivandrum	0.615	- 1.630
Quilon	0.623	- 1.573
Alleppey	0.677	- 1.062
Cochin	0.693	- 0.977
Calicut	0.349	- 1.089
Mangalore	0.362	- 1.069
Coondapur	0.508	- 0.873
Karwar	0.199	- 1.511
Goa	0.530	- 0.820
Malwan	0.686	- 0.734
Ratnagiri	0.925	- 0.625
Tarapur	0.712	- 0.720
Valsad	0.980	- 0.594
Veraval	0.163	- 1.651
Dwaraka	0.391	- 1.018

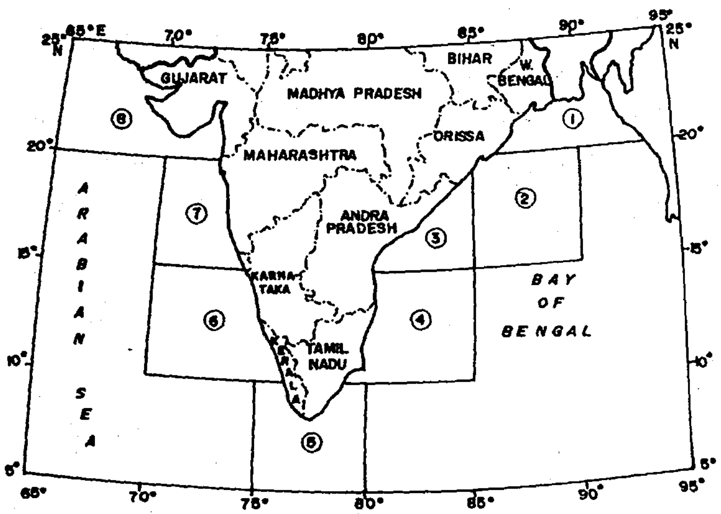

FIG.1 Map showing the grids

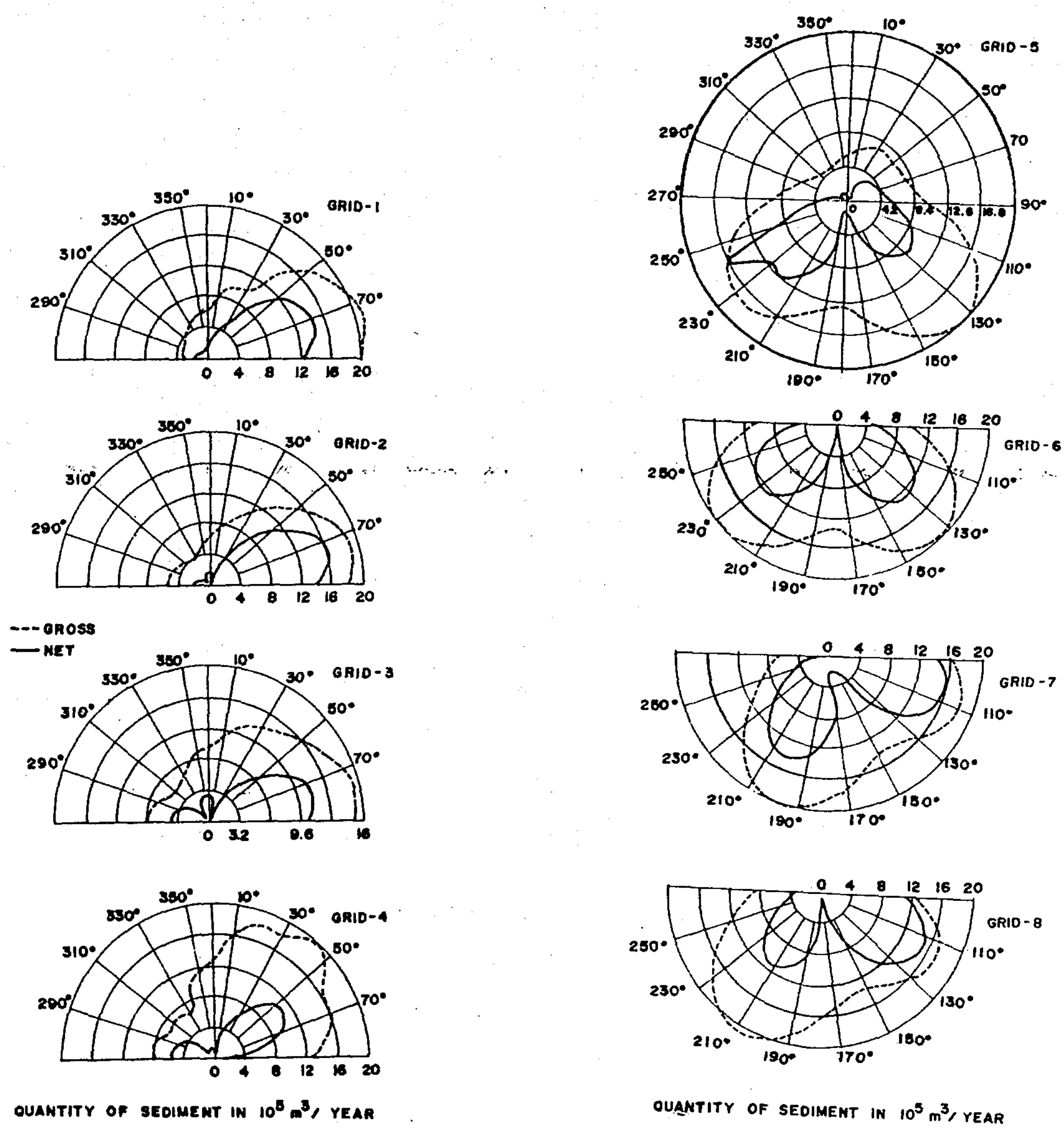

FIG. 2 Rose Diagrams: Annual Sediment Transport Rate

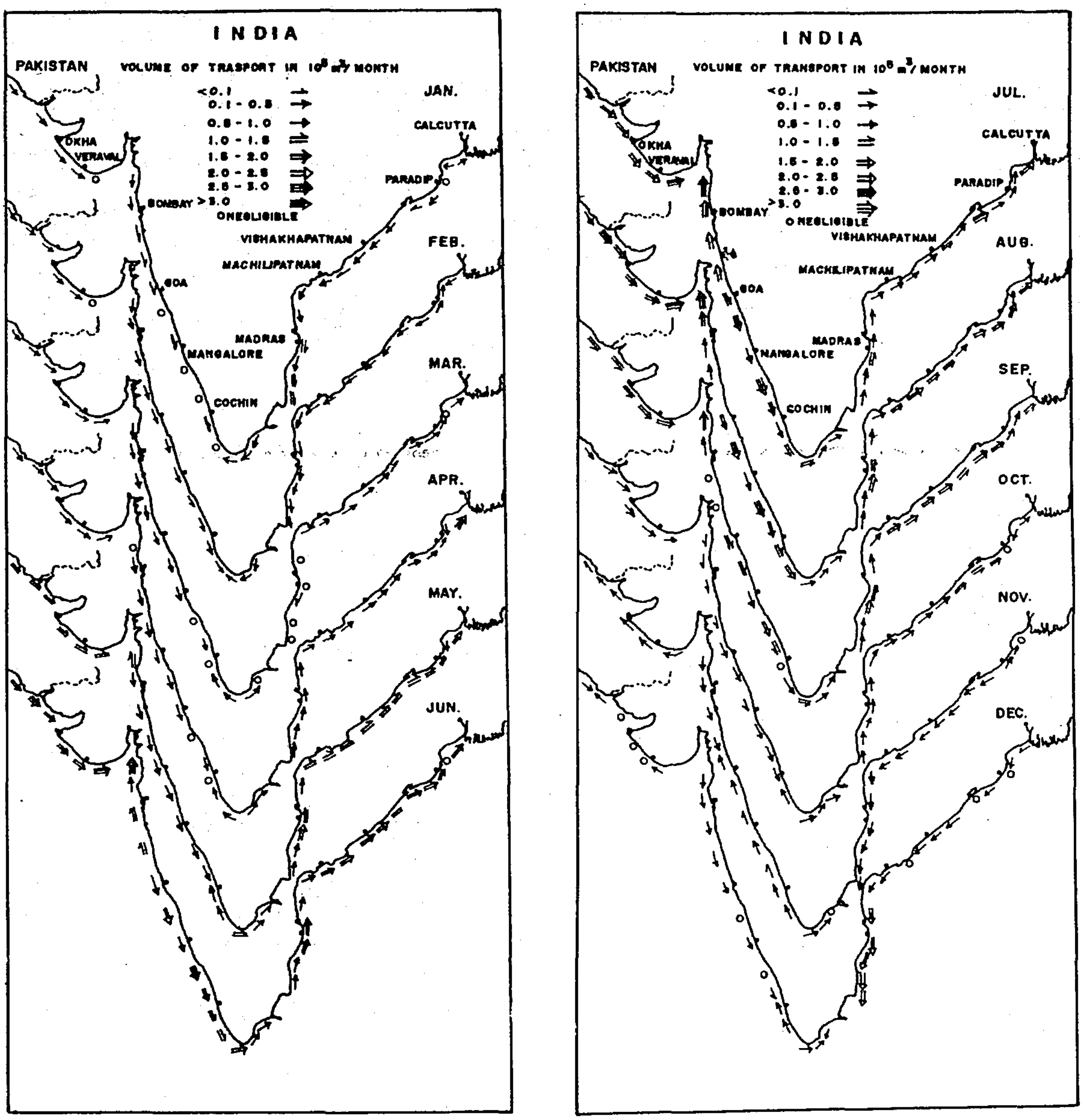

FIG. 3 Monthly Sediment Transport Rate along the Indian Coast

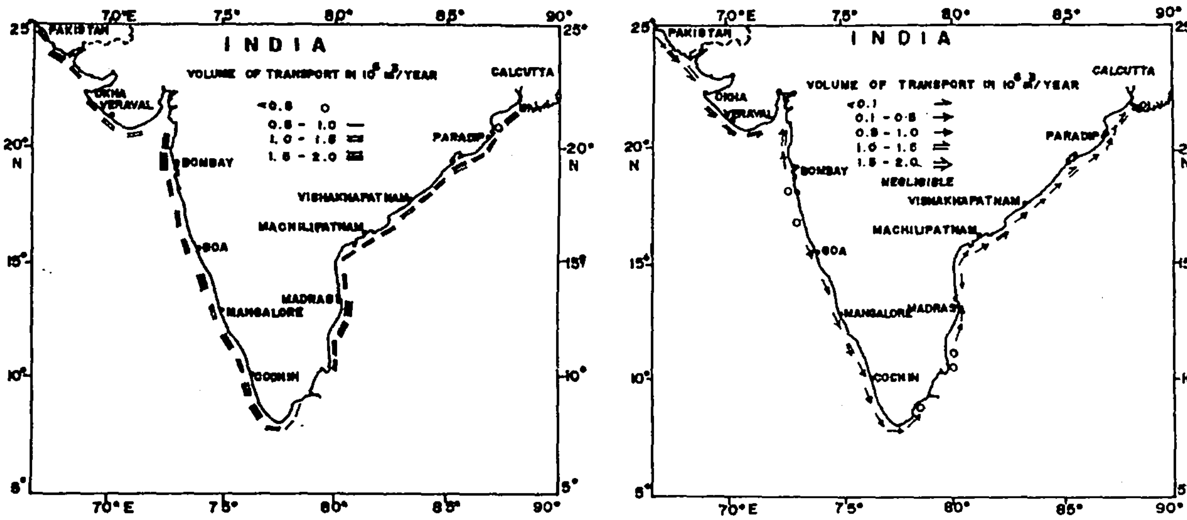

FIG. 4 Gross and Net Transport Rate along the Indian Coast