

# Climate induced variability of suspended matter and nutrient in the discharge of Kali River, Central West Coast of India

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**Abstract:** The Kali River is located in the orographically enhanced precipitation regime of the SW monsoon (SWM), and is the significant river along the central west coast of India. Study of the season variability in its discharge characteristics is important to understand the influence of the SWM precipitation on estuarine and coastal processes. The seasonal discharge data of the river is obtained during 2004, which was a normal monsoon year. We find high nutrient load in the rivers, specially in the estuarine section, during SWM as well non-monsoon season. High TSM and nutrient load in the river may be attributed to the recent deforestation associated with an unplanned expansion of Karwar township and setting up of a mega naval base. An enhanced anthropogenic load of fertilizers, insecticide and sewage due to neo urbanization is likely, and may enhance eutrophication in the estuarine and coastal regions.

Key Words: TSM, Nutrients, Kali River, South West monsoon

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**Introduction:** Understanding the role of climate on the yield, influx and dispersal pathways of particulate matter (TSM) into marine environment is crucial for sustainability of marine food web and sequestering magnitude of carbon in the marine environment (Weaver, 1989; Chauhan et al., 2005; Naqvi et al., 2009). Riverine input plays an important role for surface hydrography and marine biogeochemistry. Land derived nutrients enhance the marine productivity, which in turn is related with consumption of dissolved oxygen vis-à-vis eutrophication. Discharge magnitude and nutrient flux are important parameters in

regulating coastal and estuarine biogeochemistry. However, estimation of natural versus anthropogenic components in a river system is marred by large scale sequestering of fluvial input due to deltaic activities and the construction of recent dams. These have affected natural discharge characteristics of fluvial discharge, and hinder the evaluation of the role of precipitation regime on supply of TSM and nutrients into the estuarine and coastal region.

The central west coast of India is the only region of the Arabian Sea at which there is an excess seasonal rainfall due to orography. The area has several

short, high gradient rivers. Unlike the other large rivers of India, the Kali River of the central west coast of India is not dammed. The river has a small, estuarine mouth and virtually no large scale deltaic activities are reported from the area. Being located in the region of high precipitation ( $\sim 2700 \text{ mm y}^{-1}$ , 80% of which is confined to the rainy season of the SW monsoon (SWM)), it is ideal to decipher influence of the SWM precipitation on the fluvial influx into the sea. As a part of a national initiative to understand the influence of fluvial flux on the coastal processes, the present study is a modest beginning under the auspices of the Indian Space Research Organization (SAC and IGBP-ISRO). We have estimated river discharge characteristics during SWM and non monsoon season at 10 locations. This study is aimed at deciphering the seasonal variability in the discharge rates and spatial variability in the nutrient and suspended matter during SWM and non monsoon season of 2004.

**Study area:** The SW continental margin of India receives high rainfall (June through September) in the narrow belt of the Western Ghats. The SWM winds, laden with moisture, upon their entry into the Indian Peninsula, lose their moisture by induced condensation due to orographic factor. The Kali River originates at  $\sim 600 \text{ m}$  in the Archaean terrain of the Western Ghats, and has a catchment area of about  $\sim 4190 \text{ km}^2$ . The length of the river is 153 km, and it flows mostly in the hilly terrain. The average gradient of the river is 1:255, which reduces considerably in the estuarine region. Meso-tidal

environment prevails in the region (tidal range  $< 1.6 \text{ m} > 4 \text{ m}$ ; Varkey *et al.* 1982), and river has inland exchange of seawater during a tide cycle.

**Methodology:** In order to resolve the influence of the SW monsoon, we have evaluated the rainfall data in the vicinity of the River Kali at Karwar between 2001-2005. The average rainy days (rainfall  $> 2.5 \text{ mm}$ ), and total precipitation during each month is estimated from rain gauge data (Table 1). There exists no gauge on the Kali River. The course of the river lies in the hilly terrain and the local gradient of the river is variable. The mouth of the river is influenced by tides, with inland advection of seawater. In order to minimize the influence of these local factors, we have selected an inland station ( $14.89^{\circ} \text{ N}$ ;  $74.27^{\circ} \text{ E}$ ) which is not influenced by tidal action. The station is located in the region which is relatively flat, and this section of the river has a uniform gradient. Because of the highly seasonal rainfall (Table 1), the river discharge is expected to be regulated by rainfall and evaporation. Associated with the high gradient of the river (1:255) and short length of the river, the river is expected to have least sequestering within its basin in the hilly region. Similarly, because of high number of rainy days, which mostly occur during SWM, the river discharge shall be highly seasonal. The rainfall ceases by November in the study area and it remains similar during SWM and non monsoon months (Table 1). We have, therefore measured the river discharge during August and December 2004, which represents discharge magnitude during SWM

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average R/D	Annual Rainfall (mm)	24 hrs heaviest
2001	10.4	0	0	44	282.1	744.7	839.5	434.4	146.5	157.5	0	0	21	2659.1	R/F : 140.0
# obs	31	28	31	30	31	30	31	31	30	31	30	31		365	DT : 22
R/D	1	0	0	4	9	23	30	24	8	7	0	0			MN : 06
2002	0	0	0	8.3	185.1	1029.9	394.7	581	149.2	431.6	0	0	20	2779.8	R/F : 297.2
# obs	31	28	31	30	31	30	31	31	30	31	30	31		365	DT : 14
R/D	0	0	0	1	6	20	22	22	10	13	0	0			MN: 06
2003	0	0	0.6	0	0.2	1268.1	1174.3	555.6	272.5	66.8	0.6	0	23	3338.7	R/F : 204.6
# obs	31	28	31	30	31	30	31	31	30	31	30	31		365	DT : 20
R/D	0	0	0	2	3	23	28	26	16	27	0	0			MN : 06
2004	0	0	0	0	271.6	729.2	746.4	664.8	273.6	124.3	69.8	0	21	2879.7	R/F : 142.5
# obs	31	29	31	30	31	30	31	31	30	31	30	31		366	DT : 13
R/D	0	0	0	1	21	22	25	25	9	5	4	0			MN : 08
Average rainfall (mm)	2.08	0	0.12	10.46	159.02	945.64	630.98	447.16	168.36	156.04	14.08	0		2533.94	

MRF = Total monthly rainfall in mm.  
#obs = No of observations in the month (number of observations zero means observations are not recorded during the month)

R/D = # of rainy days during SW monsoon (having rainfall more than 2.4 mm)

**Table 1.** Monthly Rainfall Data (mm) for Station A) Karwar, District: Kanara North 14° N 74° E

and non-monsoon seasons. Measurements include estimation of water elevation above the river-bed (six across-channel measurements), and time and depth averaged flow (using a CONtrol current meter at 1 h intervals). Discharge rates were estimated from the time and depth averaged flow rates, river cross-sections and water elevations above the riverbed following the methodology of *Stern et al.* (1986, 1991).

Suspended particulate matter in the river water is estimated at 10 stations. The collection time in the estuarine samples was mid-tide synchronous during August and December of 2004 (Fig 1). Persistent inclement weather limited the sampling density. The protocol of JGOFS (matter retained on <0.45- $\mu\text{m}$  Opti pure fiber filter paper; UNESCO 1994) was followed for TSM estimation. The water samples at these stations (Fig 1) were analyzed also for  $\text{NO}_3^-$  and  $\text{PO}_4^{3-}$  using the methods of *Grasshoff et al.* (1983).

#### **4. Results and Discussions:**

Seasonal, spatial variations in TSM are presented in Fig 2. We have found high seasonality in the distribution of TSM during SWM and non – monsoon season. TSM pattern from the estuarine and in the inland section of the river is rather different. During SWM, the hilly section of the river is characterized by higher TSM. The estuarine section, however, has reduced turbidity (Fig 2). We found many fold reduction in the TSM pattern during December 2004 in the estuarine and hilly sections of the study area (Fig 2). The study area receives ~ 2700 mm of rain and has ~ 20 rainy days month<sup>-1</sup> during SWM

(Table 1). The precipitation magnitude is highly seasonal, and virtually no meteoric water is available after cessation of the NE and the SW monsoons (Table 1). The river originates in the Western Ghats (elevation ~ 1900 m above mean sea level), and is short (~153 km in length). Despite prevalence of a chemical weathering regime, high precipitation in the hilly terrain appears to sustain good yield of particulate suspended matter. We attribute high yield and supply of TSM into the river because of recent deforestation in the catchment area of the river. A high gradient of the river appears conducive to carry TSM from the hinterland into the estuarine and coastal region rather rapidly. We, therefore, link higher TSM in the river during the SWM with intense precipitation regime and anthropogenic influence. The reduction in TSM in the estuarine region of the river during SWM may stem from sequestering of TSM associated with (i) clay flocculation as a result of interaction of sea - freshwater because of inland intrusion of seawater which interact with the fresh water discharge during flood- ebb cycle and (ii) reduction in flow speed due to fanning out of river-water into a wider estuary. A many fold reduction in TSM during the post monsoon has been observed. This implies that the supply of most of the terrigenous particulate matter into the estuary is from the hinterland. From the salinity reduction off the mouth of the river and over the entire inner shelf (Levitus et al., 1994), it is also evident that this discharge is redistributed over the shelf (Chauhan and Gujar, 1996). Higher deforestation in the hinterland due to

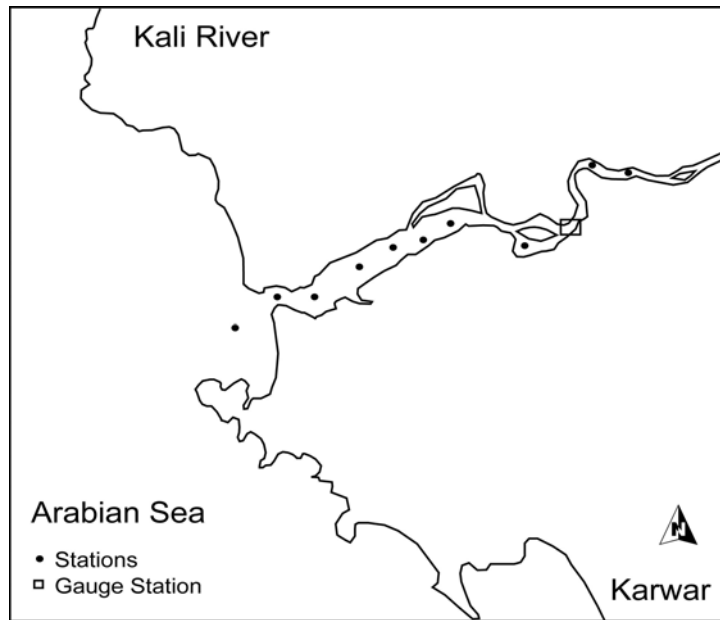


Fig 1: Study area along with sampling stations. The location of the station at which the river discharge was measured is also shown.

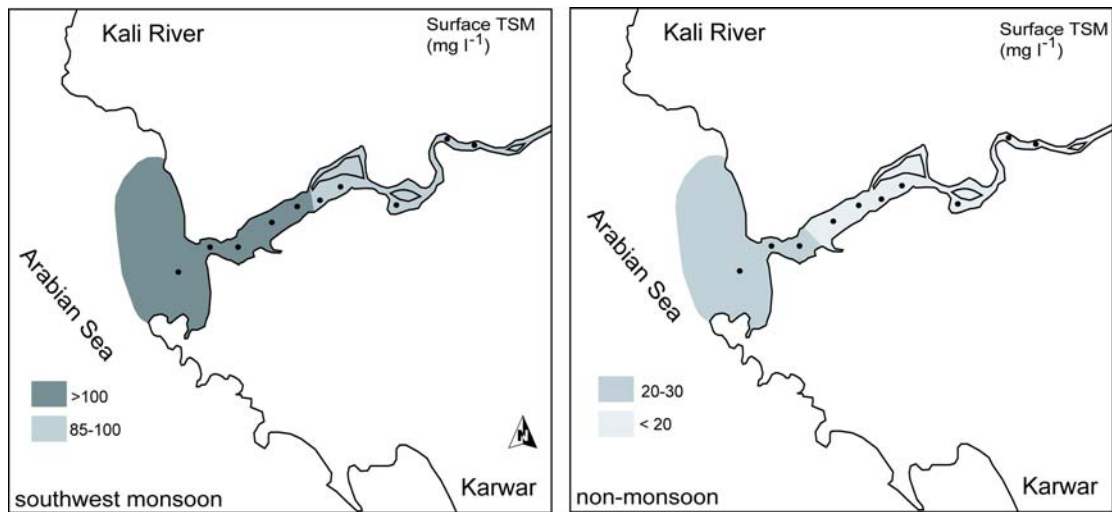


Fig 2. Distribution of TSM for August (SWM) and December (post-monsoon) of 2004 in the Kali River.

anthropogenic loading may further enhance turbidity of the river. A large sequestering of the particulate matter over the year may lead to enhance silting of the estuarine and coastal regions, and is detrimental to the maintenance of the channel of the local harbor and for the naval base. The enhanced turbidity has implication also for the marine biogeochemical processes, and availability of sunlight to the benthic marine community.

The nutrient distribution in the estuarine and hilly regions of the river is presented in Fig 3. We have found high nitrate and phosphate in the river waters during the SWM. Even upon cessation of rains, the nutrients content in the estuarine region does not dwindle. We have found higher nutrient concentration in the estuarine waters compared to the inland region, even upon the dwindling of the river discharge in December 2004. This implies that the natural land processes in the hilly hinterland may not be a major contributor of nutrients. The high content of nutrients in the estuary, round the year, specifically upon the cessation of the rains, points to a local supply through anthropogenic activities. Higher nutrient load in the estuarine waters therefore stems from the anthropogenic activities, which are haphazard and unplanned. This implies that the coastal agriculture, aquaculture establishments and sewage discharge from the neo-townships are playing a vital role. Sewage and chemical fertilizer loadings are likely to be enhanced further, as coastal regions in the area is dependent on agriculture and several new aquaculture activities are mushrooming. Because marine

productivity in the coastal waters is regulated by the availability of the nutrients (Banse., 1987) and the Kali River appears to supply large amount of nutrients into the sea, it is likely to alter the existing dynamic equilibrium in the estuarine biogeochemical processes. High marine productivity has been found to enhance production and subsurface supply of organic carbon in the marine environment (Naqvi et al., 2009). Besides primary production, an enhanced deforestation or land derived organic carbon (specifically sewage) are also known to consume dissolved oxygen and contribute to eutrophication in the estuarine and the coastal waters (Naqvi et al., 2009). The results of the present study suggest that the Kali River is a depo-center of land derived fertilizers, forest contribution and sewage, which is likely to influence higher supply of particulate organic carbon, colored dissolved organic matter and may enhance the in situ production of carbon through primary productivity. These factors may cumulatively consume more dissolved oxygen (DO) of the estuarine and coastal waters. DO of the estuarine water are crucial for sustaining the quality of seawater, COD, BOD and regulates mortality of marine life. Studies from the continental shelf off the mouth of Kali River has reported prevalence of hypoxia in the deeper subsurfaces (Kumar et al., 2004; Naqvi et al., 2009; Chauhan et al., 2010). Salinity of the sea water during SWM is found to be lower (Levitus et al., 1994) due to fluvial flux. This implies that the SWM climate and the enhanced fluvial supply from the study area play a vital role on marine and estuarine biogeochemistry.

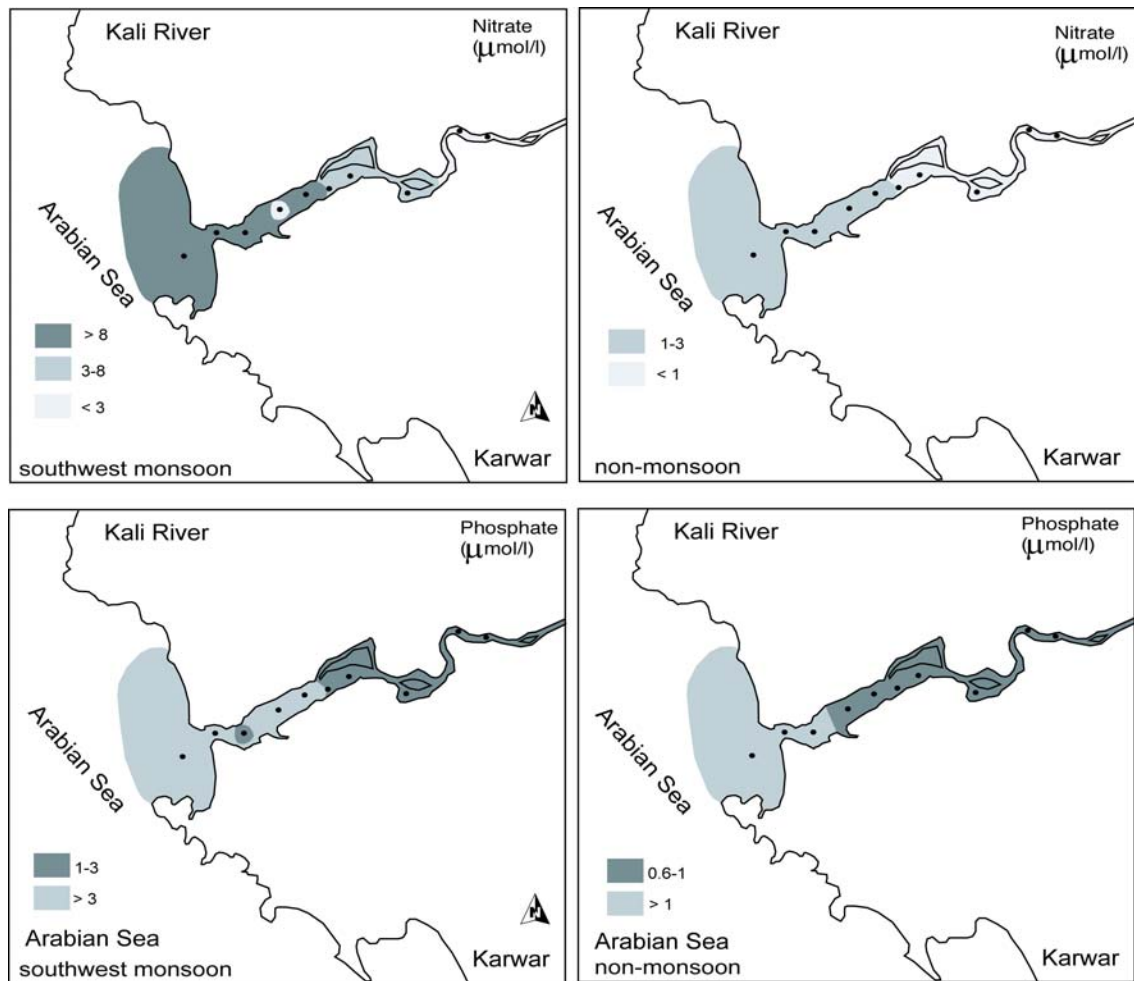


Fig 3. Spatial distribution of nutrients (phosphate and nitrate) in the Kali River during SWM and non monsoon season.

Because supply of nutrients and land derived organic matter in the Kali estuary are regulated by the anthropogenic loading, the unplanned expansion of the township and indiscriminate use of chemical fertilizers are expected to enhance magnitude of eutrophication in the coastal and estuarine waters. If such trend is not arrested, it is likely to induce higher fish mortality in this area.

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## References

- Banse, K. (1987), Seasonality of phytoplankton chlorophyll in the central and northern Arabian Sea, *Deep-Sea Res.*, 34,713–723, doi: 10.1016/0198-0149(87)90032-X.
- Chauhan, O. S., Gujar, A. R., 1996. Surficial clay mineral distribution on the southwestern continental margin of India: evidence of input from the Bay of Bengal. *Cont Shelf Res.*, 16, 321-333. doi:10.1016/0278-4343(95)00015-S.
- Chauhan, O. S., Vogelsang, E., Basavaiah, N., Kader, U. S. A., 2010. Reconstruction of the variability of the southwest monsoon during the past 3 ka, from the continental margin of the southeastern Arabian Sea. *J Quaternary Sci.*, 25(5), 798–807. doi: 10.1002/jqs.1359.
- Grasshoff, K., M. Ehrhardt, and K. Kremling (1983), *Methods of Seawater Analysis*, Verlag Chemie, New York.
- Kumar, P. S., Narvekar, J., Kumar, A., Shaji, C., Anand, P., Sabu, P., Rijomon, G., Josia, J., Jayaraj, K. A., Radhika, A., Nair, K. K. C., 2004. Intrusion of the Bay of Bengal water into the Arabian Sea during winter monsoon and associated chemical and biological response. *Geophys Res Lett.*, 31, L15304. doi:10.1029/2004GL020247
- Levitus, S., Burgett, R., Boyer, T. P., 1994. *World Ocean Atlas: Salinity*, NOAA Atlas. NESDIS, 3, US Dept of Commerce, NOAA, pp. 99.
- Naqvi, S. W. A., Naik, H., Jayakumar, A., Pratihary, A. K., Narvenkar, G., Kurian, S., Agnihotri, R., Shailaja, M, S., Narvekar, P. V., 2009. Seasonal anoxia over the western Indian continental shelf. In: Wiggert, J.D., Hood, R. R., Naqvi, S. W. A., Brink, K. H., Smith, S. L., (Eds.), *Indian Ocean biogeochemical processes and ecological variability*. Geophysical Monograph Series, Washington, DC, USA, 185, pp. 333-345.
- United Nations Educational, Scientific, and Cultural Organization (UNESCO), 1994. *Protocols for the Joint Global Ocean Flux Study (JGOFS) Core Measurements*, in *Manual and Guides 29*, Paris, Scientific



- committee on oceanic research, pp. 170.
- Stern, M. K., Jr. J. W. Day, and K. G. Teague (1986), Seasonality of materials transport through a coastal freshwater marsh: riverine versus tidal forcing, *Estuaries*, 9, 301-308.
- Stern, M. K., Jr. J. W. Day, and K. G. Teague (1991), Nutrient Transport in a riverine influenced tidal freshwater bayou in Louisiana, *Estuaries*, 14, 382-394.
- Varkey M. J., V. Kesava Das G. N. Swamy, P. S. Joseph and J. S. Sastry (1982), Wave (swell) atlas for Arabian sea and Bay of Bengal. Technical Report, National Institute of Oceanography, Dona-Paula, Goa, India. 385pp.
- Weaver, C. E. (1989), Clays, Muds and Shales. Dev. In Sedimentol., vol. 44, Elsevier, Amsterdam.