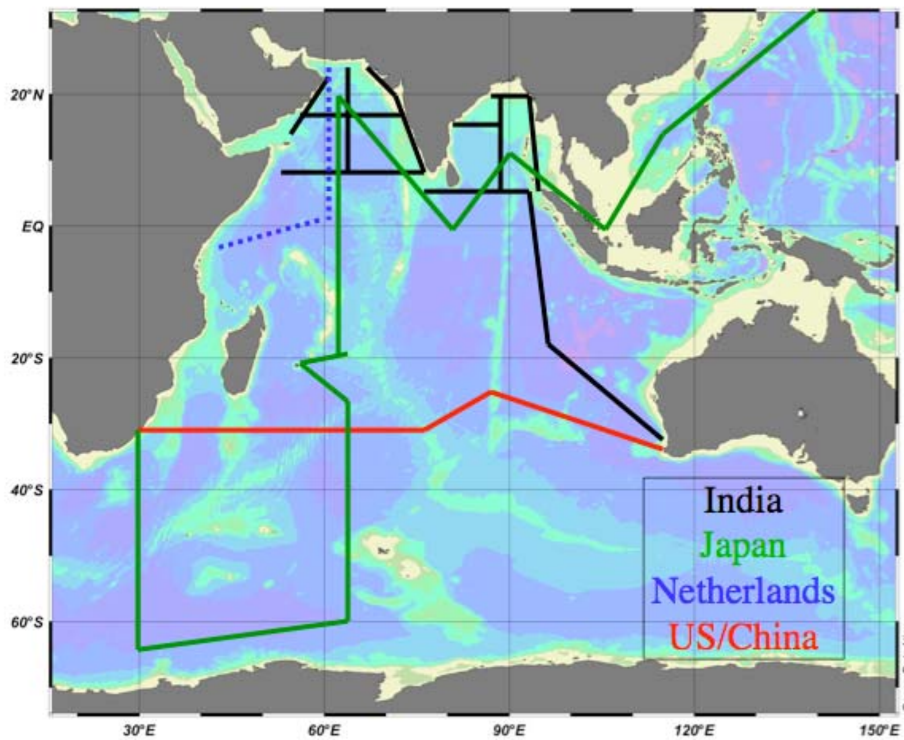
GEOTRACES Indian Ocean Planning Workshop

International Centre

Goa, India

24-26 October, 2007



Preface:

GEOTRACES held a series of planning workshops in 2007, one each for the Atlantic, Pacific and Indian Oceans, as well as one that focused on model/data synergy.

Basin planning workshops were designed to refine the scientific objectives identified in the GEOTRACES Science Plan, to place them into a framework of specific sections and process studies, and to identify nations that are prepared to take the lead in implementing these efforts. An important element of this process is to provide the justification and rationale for the recommended studies. Reports from these workshops represent an interim step in developing a global field program for GEOTRACES. The reports will be posted on the GEOTRACES web site www.geotraces.org and will be used as a resource throughout the planning and implementation of the GEOTRACES program. It is not intended that these reports will be printed for widespread distribution. Rather, the GEOTRACES Scientific Steering Committee will extract highlights from the individual reports to create an overview document for public presentation and promotion of the global GEOTRACES program.

This report summarizes the outcome of that process for the Indian Ocean.

Acknowledgements

Support for the GEOTRACES Indian Ocean workshop was provided by the Ministry of Earth Sciences, Government of India, New Delhi, the Scientific Committee on Oceanic Research, and the U.S. National Science Foundation.
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1.0 Introduction

The Indian Basin Planning Workshop, held at the International Centre in Goa, India, October 24-26, 2007, brought together 60 scientists representing 7 countries (Appendices 1 and 2) to plan the GEOTRACES sections in the Indian Ocean. Participants for the workshop were solicited by broad announcements in a variety of ways. This included town meetings held during the Fall AGU meeting (December 2006, San Francisco) and during the ASLO winter meeting (February 2007, Santa Fe). Additionally, announcements were made electronically via the GEOTRACES email list, assembled from collective expressions of interest received via multiple routes. A general announcement was posted on the GEOTRACES web site, as well.

The meeting opened with keynote talks focusing on circulation of the Indian Ocean, atmospheric deposition of **trace elements and their isotopes** (TEIs), and the role of TEIs in marine biogeochemical cycles and as limiting micronutrients (Appendix 1). Participants then heard five talks about planned and proposed research programs in the Indian Ocean that hold relevance to GEOTRACES objectives; these research programs figured heavily in the deliberations of the Working Groups (see working group reports below, as well as Figure 1). Many interesting ideas were presented in approximately 30 brief advocacy statements (5-minute oral presentations), including five proxy presentations made by the meeting co-chairs on behalf of interested parties that were unable to attend the workshop. Proxy presentations included expressions of interest from France, Germany, the United Kingdom and the Netherlands. Ideas and interests expressed during the advocacy statements figured prominently in working group deliberations.

Following the precedent set by the Pacific and Atlantic workshops, there was an extended plenary discussion leading to the identification of working groups. Upon considering an initial suggestion that the Indian Ocean be divided into multiple northern, equatorial and southern regions, it was determined that substantial overlap exists among many of the adjacent regions. Consequently, participants reduced the number of working groups to three: the Arabian Sea, the Bay of Bengal (each interpreted broadly to extend south of the equator) and the Southern Ocean. Working groups deliberated throughout the afternoon of Day 2, and made plenary presentations of their preliminary recommendations at the end of the day. Participants reconvened on the morning of Day 3 and held extensive discussion that led to a number of suggestions for each of the working groups. Working groups used these suggestions to revise their recommendations for sections and process studies, and presented the revised plans in plenary session after lunch. Following a brief discussion, each working group report was endorsed by the full body of participants in plenary session. The written reports that follow summarize the oral presentations endorsed by workshop participants.

An initial plan, with cruise tracks and logic for each region covered, had been assembled by the end of the three-day meeting. Countries were identified that would take the lead in implementing the cruises, and partnerships between countries were outlined that would permit studies to be completed in different seasons within regions (especially the Arabian Sea) that experience strong seasonal forcing by the monsoons. Crossover points between cruise tracks were identified that will afford the opportunity for intercalibration. The proposed GEOTRACES cruise tracks for the Indian Basin are presented in the final section of this report.

2.0 Common Issues

In addition to discussion of scientific objectives within each of the regions represented by the working groups, there were extensive discussions of four general topics: intercalibration, data management, **Exclusive Economic Zones** (EEZ), and trace-metal clean sampling systems.

2.1 Intercalibration

Many of the participants in this workshop were relatively new to GEOTRACES, and were previously unfamiliar with the ongoing intercalibration effort. Rob Sherrell gave a formal presentation on the topic, and urged all participants to contact him or the leader(s) of the appropriate self-assembled working groups to express an interest in participating and to gain access to intercalibration samples. Contact persons for the 15 TEI groups are provided as Appendix 3.

2.2 Data Management

Data management and a common data policy are vital to the success of GEOTRACES. Chris Measures described the status of the GEOTRACES data management system as well as the essential features of the tentative policy (yet to be approved by the GEOTRACES SSC). India, like other nations with large numbers of oceanographers, has its own national data centers. It is proposed that scientists in India initially submit data from their GEOTRACES cruises to their national center, and notify the international GEOTRACES Data Management Office (DMO) of the submission. The DMO can then make arrangements to link the Indian data center(s) to the international GEOTRACES data system, as will be done for other national data centers that support GEOTRACES work. Many nations bordering the Indian Ocean do not have dedicated ocean data centers, and for scientists in these nations the GEOTRACES DMO can serve as the primary data repository.

2.3 EEZ Issues

Each nation has restrictions concerning sampling within its EEZ. Most of the discussion here focused on India, whose EEZ would be sampled extensively in following the recommendations of the working groups described below. Work within the Indian EEZ will require use of Indian vessels. Where cruises cover both EEZ and international waters, there must be advance planning, on a cruise by cruise basis, to determine whether the preferred strategy is to have international participants aboard the cruise, or to have the cruise staffed exclusively by Indian nationals. In the latter case, samples may be collected for international collaborators if necessary to complete the list of GEOTRACES key parameters, or to support relevant complementary research projects.

2.4 Trace metal clean sampling systems (training/outreach)

No nation bordering the Indian Ocean has a complete facility for trace-metal clean sampling at sea (e.g., non-contaminating rosette with GO-Flo or equivalent bottles;

Kevlar or other non-contaminating wire; clean lab with HEPA filtered air for processing samples). Acquisition of one or more such systems for use in the Indian Ocean would be a valuable asset to GEOTRACES, and there was a strong interest among Indian scientists at the workshop to acquire such a system. Clean sampling systems of somewhat different design have been constructed by scientists in Japan, the Netherlands and the U.S. Scientists in India are currently examining these designs as a basis for a proposal to acquire a system to be used aboard Indian research vessels. Ideally, the design to be selected would be portable, allowing it to be transferred among ships as needed to serve the Indian oceanographic community. Whatever design is selected, whether a copy of an existing system of a hybrid involving features of multiple systems, scientists currently operating those existing systems stand ready to assist their Indian colleagues in the design, construction, and operation of the clean sampling system with the goal of making a new sampling system ready for use aboard GEOTRACES cruises and those of related programs as quickly as possible.

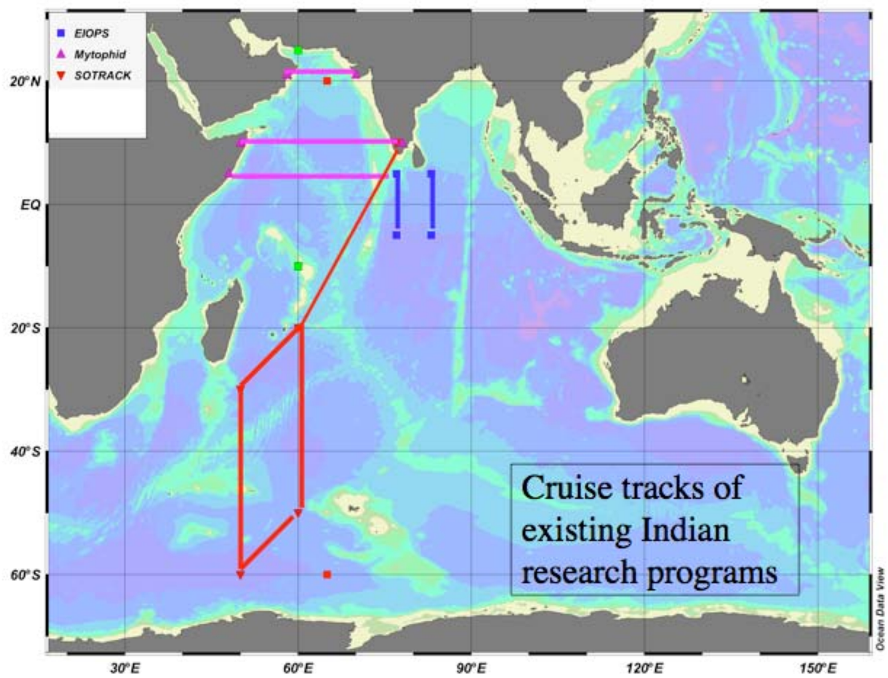


Figure 1. Planned cruise tracks of existing or proposed ocean research programs in India that involve objectives relevant to GEOTRACES, and for which opportunities to sample for GEOTRACES objectives may be possible. This map was generated on the basis of presentations made during the workshop, without actual cruise plans, and therefore represents approximate cruise tracks. A recommendation of the workshop is that opportunities for sampling on behalf of GEOTRACES during these cruises be explored further.

3.0 Report of the Arabian Sea and Western Indian Ocean Working Group

Chair: S. Prasanna Kumar, NIO, Goa
Rapporteur: Mark Baskaran, Wayne State University, Detroit, MI, USA

Participants:

Sunil K. Singh	PRL, Ahmedabad
M.M. Sarin	PRL, Ahmedabad
Vineet Goswami	PRL, Ahmedabad
W. Rahaman	PRL, Ahmedabad
K. Sajan	CUSAT, Kochi
C.H. Sujatha	CUSAT, Kochi
Karen Casciotti	WHOI, Massachusetts, USA
Sushant Naik	NCAOR, Goa
C.M. Laluraj	NCAOR, Goa
Manish Tiwari	NCAOR, Goa
A.C. Narayana	Univ. of Hyderabad
Hilda Joao	NIO, Goa
V.Ramaswamy	NIO, Goa
D.V. Borole	NIO, Goa
B. Nagendra Nath	NIO, Goa
P. Divakar Naidu	NIO, Goa
Kuria Ndungu	Stockholm University, Sweden
Busnur Manjunatha	Mangalore University
Joseph Kamau	KMFNI, Kenya
Jim Moffett	Univ. of Southern California, USA

3.1. Introduction:

The working group on the “Arabian Sea and Western Indian Ocean” discussed and identified several research problems and biogeochemical processes. This report comprises two sections: 1) ***Water column and Atmosphere*** where we discuss the highly important processes (spatial and temporal) of scientific relevance to the major goals of GEOTRACES; and 2) ***Sedimentary processes*** where we discuss the input and output fluxes of TEIs between the sediment and the water column. We end this report with a set of recommendations for implementation.

3.2. Problems/Questions/Processes:

3.2.1 Water Column & Atmosphere:

- Characterization and quantification of atmospheric dust input of TEIs (including REEs) and nutrients to the Arabian Sea and its relationship to biological productivity

- Fractionation, partitioning, and quantification of redox-sensitive elements and other TEIs through estuaries

- Sources, fate, and transport of TEIs from coastal (West coast of India and Kenya) and marginal seas (Persian Gulf and Red Sea) into the Arabian Sea

- Impact of upwelling and photosynthesis on spatial and temporal variability of TEIs and nutrients

- Speciation and cycling of Hg and Cu

- Temporal variations in scavenging and cycling of particle-reactive radionuclides (^{10}Be, ^{210}Po, ^{210}Pb, Th isotopes); quantification of the export fluxes of carbon and other TEIs using these radionuclides as tracers

- Quantification of the temporal (pre-, during and post-monsoon seasons) and spatial variability of the removal fluxes of particle-reactive species (concentrations and isotopes: U, Re, Os, Mo, V, Cr, Co, Nd, Pb, Po, Be) and nutrients in the water column, in particular in the Oxygen Minimum Zone (OMZ)

- Iron studies: Fe-Limitation – when does it takes place – during peak upwelling or tail end of upwelling?; during winter/summer monsoon? Sources of iron: atmospheric, lateral transport, shelf-slope exchange, benthic sources; mass balance of Fe; advectional input from the Oman shelf by the *Ras Al Had* jet; Speciation of Fe

- Distribution of N and Si isotopes in the Arabian Sea and its cycling in sediments (e.g., denitrification); nitrate utilization in the upwelling off Somalia

3.2.2 Sediments and Sediment Traps

- Fluxes and speciation of TEIs (e.g., S, C, N) to and from sediments in oxic and anoxic environments
- Investigation of selected TEIs in sedimentary record as tracers to study circulation
- High-resolution sediment trap studies to quantify the fluxes of TEIs on weekly to inter-annual time scales

3.3. Related Programs and Cruises Already Planned:

- Japanese Cruise in 2008 along 65°E during winter monsoon
- Information about plans for a cruise in the Arabian Sea by The Netherlands was provided by e-mail and presented at the workshop by proxy. The plan presented for the Dutch Cruise (cruise planned for 2011 or beyond) called for a meridional section along approximately 60°E, from the Seychelles toward Pakistan. If the Japanese cruise along 65°E occurs during the winter monsoon, and an Indian cruise occurs during the summer monsoon, then the working group suggested that Dutch scientists explore the possibility of repeating the transect along 60 °E during the fall inter-monsoon period (September-October months). Note, also, the recommendation below that the Dutch cruise be adjusted from 60°E to 65°E to reoccupy the sections of Japan and India.
- NCAOR (**N**ational **C**enter for **A**ntarctic and **O**ceanographic **R**esearch, India) section along 65°E from 10°N to 18°S, twice a year (winter & summer monsoon) for 3 years (from 2008-2010)

3.4. Proposed Cruises/Process Studies and Justification:

<u>Numbers are keyed in Figure 3 below</u>

Track-1: Section along 65°E – since a Japanese cruise is already planned to occupy this transect during the winter season, we propose that a cruise from India occupy the section during the summer monsoon season

Track-2: Variations in the atmospheric dust input across OMZ gradient and its implications to biogeochemical cycling of TEIs

Track-3: To quantify the zonal gradients of TEIs between the eastern boundary and western boundary upwelling zones

Tracks-4 to 6: The section along the eastern and western boundaries of the Arabian Sea is aimed at quantifying the fluxes of TEIs across the shelf to the open ocean.

3.5. Recommendations for Implementation:

1) Explore the possibility with the Dutch Group of undertaking the following during their proposed cruise during 2011):

i) Adjust the proposed meridional section from 60°E to 65°E to overlap with cruise tracks of Japan and India, and consider running the cruise during the Fall inter-monsoon period (September-October period); and

ii) Extending their cruise track to transect through the Kenyan coastal and shelf waters to examine along-shore transport of TEIs, potentially linking these to Kenyan studies of TEI fluxes from estuaries.

2) Group the sampling stations into two categories:

i) measurements of core parameters in all the stations; and

ii) measurements of all parameters in select stations.

3) Explore the possibility of conducting a GEOTRACES sampling cruise onboard SAGAR KANYA in 2009, in conjunction with the ongoing biogeochemical measurements for which Chris Measures of Univ. of Hawaii agreed to bring his clean-sampling gear.

4) We recommend that the international GEOTRACES group assist in capacity building and human resource development for nations surrounding the Indian Ocean whose scientists are involved with the GEOTRACES program with training in the methods for ultra clean water sampling for TEIs.

5) Scientists in Germany have a long history of working in the Indian Ocean, and there is a strong interest among GEOTRACES scientists in Germany in studying TEI cycles in the Arabian Sea. However, German GEOTRACES scientists are committed to projects in polar oceans and to research on oxygen minimum zones in the tropical Atlantic and Pacific Oceans through 2012. It is unlikely that a German cruise to the Arabian Sea could be mounted before these projects are completed. Nevertheless, individual German scientists are interested in participating in international cruises in the Arabian Sea and there is an interest over longer time scales to extend German research on OMZ processes to the Arabian Sea, with the goal of comparing processes in this region to those in analogous regions of the tropical Atlantic and Pacific Oceans.

Specific areas of research interest for German scientists include:

a) Riverine sources (Indus, Narmada, Tapti) of TEIs,

b) Submarine groundwater discharges,

c) Dust input from Arabia,

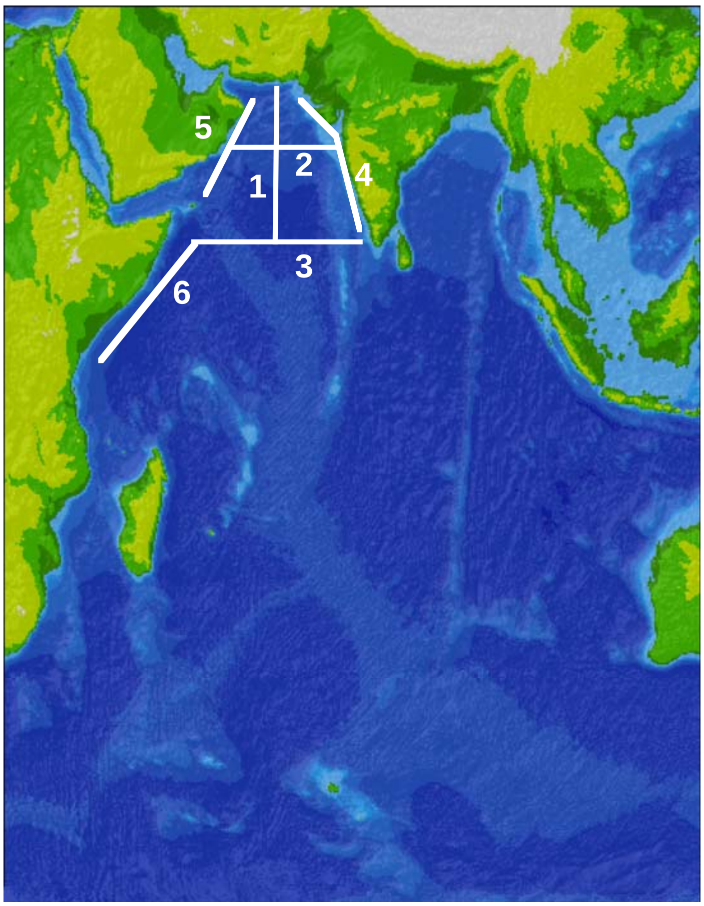
d) TEI mobilization from OMZ sediments, and

e) Boundary scavenging, especially in high productivity regions surrounding the Arabian Sea.

(contact Peter Croot <pcroot@ifm-geomar.de>), In addition to these research objectives, German GEOTRACES scientists are eager to contribute to the development of clean sampling systems and analytical techniques for scientists in nations surrounding the Indian Ocean.

Interested scientists and primary contact

Peter Croot (<pcroot@ifm-geomar.de> Fe redox and speciation, other biometals)
Martin Frank (Si, Nd and Hf isotopes)
Jan Scholten (Th isotopes)



1. 20ºN - 7ºN along 65ºE
2. Along 20ºN off Gujarat Coast – Omani coast
3. Along 7ºN from 78ºE – 64ºE
4. Parallel to west coast of India for 5ºN – 24ºN
5. Along Omani coast
6. Along Kenyan Coast

Figure 2 Proposed cruise tracks in the Arabian Sea

4.0 Report of Bay of Bengal Working Group

Prof. W. S. Moore, Chair
Prof. T. M. Church, Co-Chair
Dr. V.V.S.S. Sarma, Rapporteur
Dr. R. Rengarajan
Dr. M. Charette
Dr. Koushik Dutta
Dr. Dileep Kumar
Dr. Mohan
Dr. N. S. Sarma
Mr. Ravi Bhushan
Mr. Gyana Ranjan Tripathi
Dr. Supriyo Chakraborti
Dr. A. Sarkar
Mr. Valarala

4.1. Introduction

This report is based on discussions of a 14-member working group formed during the GEOTRACES Indian Ocean planning workshop. The report was presented to members of the entire workshop and modified after discussion. Here we present an outline of issues associated with oceanographic processes in the Bay of Bengal (BoB), a brief review of scientific achievements in the BoB, and a proposed work plan to address the issues we have raised.

A major forcing factor in the BoB is the combined flow of the Ganges and Brahmaputra Rivers. These rivers enter the northern BoB from India and Bangladesh to form a large plume of sediment and fresh water (Figure 3). The riverine outflow during the SW monsoon is so large that the BoB can effectively be considered an estuary of this giant river system.

The Ganges and Brahmaputra Rivers drain the rapidly weathering, tectonically active Himalayan mountain range. On an annual basis the Ganges-Brahmaputra River system ranks first in the supply of sediment and fourth in supply of water to the ocean. Most of the sediment is discharged during high river flow in June-September. At peak flow in August, the rivers contribute 86000 m^3s^{-1} of water and 1.3×10^5 kg s^{-1} of sediment. This decreases to an average of 5800 m^3s^{-1} of water and 1.5×10^3 kg s^{-1} of sediment during lowest flow in March.

During high discharge the entire river mouth is filled with fresh water that is funneled through the many channels that occupy the delta. Most of the river flow during low discharge is through the main or Shahbazpur Channel between Bhola and Hatia Islands. The shelf in this eastern section of the delta is broad and shallow, averaging 7 m depth for a distance of 50-100 km from shore. Beyond the 10 m isobath, depths increase abruptly over most of the shelf. In the western section a deep submarine canyon, the

Swatch of No Ground, is incised into the shelf. Here a large fraction of the fine-grained sediment is funneled to deep water to form the Bengal fan.

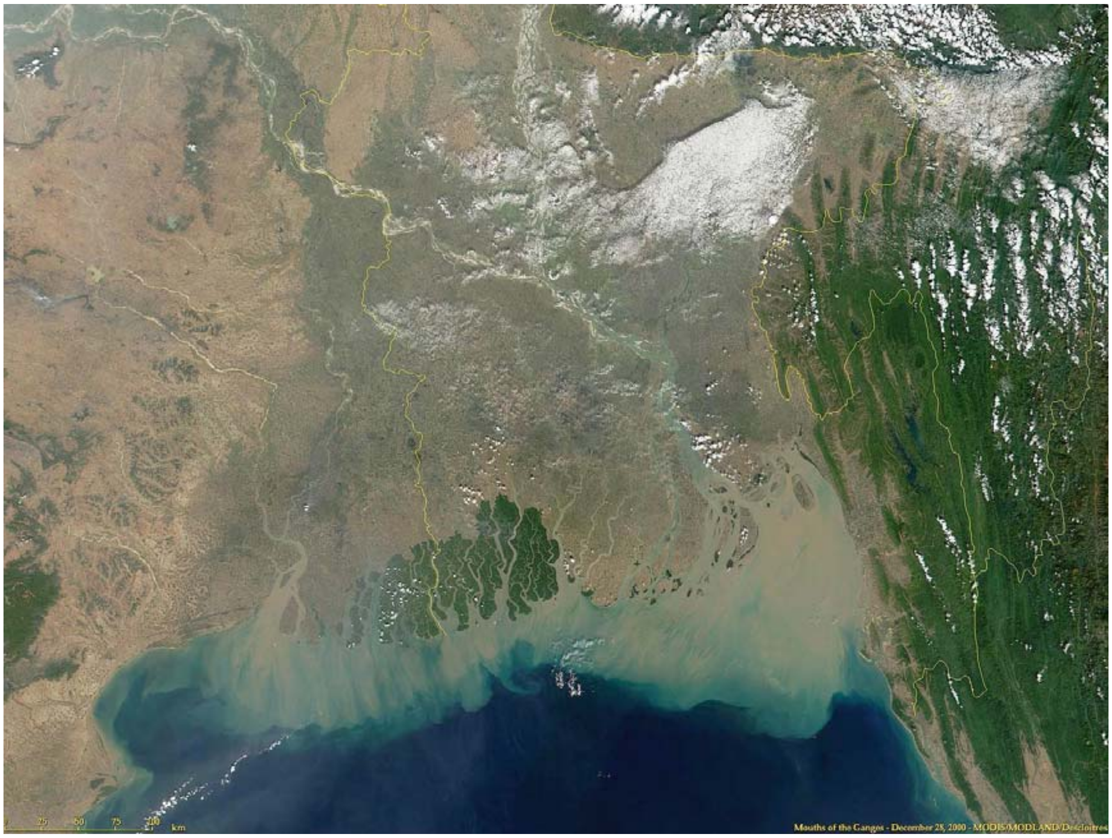


Figure 3. The mouths of the Ganges-Brahmaputra-Megna Rivers. (Courtesy of NASA at http://oceancolor.gsfc.nasa.gov).

The Ganges and Brahmaputra Rivers influence ocean chemistry through their unique river water chemistry and large flux of immature sediment. The flux and isotopic ratio of strontium from the Ganges-Brahmaputra Rivers to the ocean has become a matter of controversy in terms of its lithologic source (silicate vs. carbonate) and its corresponding isotopic ratio. Special attention has been focused on fluxes of Sr because the highly radiogenic composition of $^{87}Sr/^{86}Sr$ from this system plays a significant role in determining the present day oceanic ratio. Changes with time in Sr flux and isotopic ratio certainly affect the marine paleo record.

The Ganges and Brahmaputra Rivers also affect the inventory and isotopic composition of dissolved Os in seawater as well as its spatial homogeneity (Figure 4). As far as we know the Ganges River is the most radiogenic large river on Earth ($^{187}Os/^{188}Os$

= 1.5-2.9; Levasseur et al., 1999; Sharma et al., 1999). The Bay of Bengal is also heavily influenced by atmospheric pollution from fossil fuel burning, which may also impact Os in surface seawater.

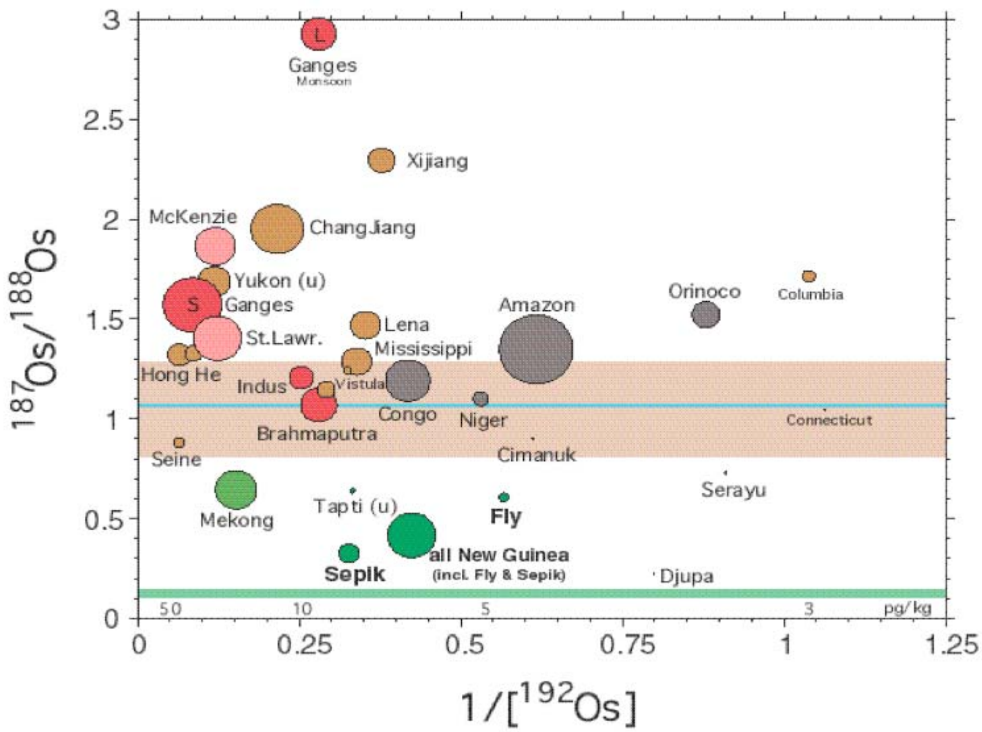


Figure 4. Os concentration (expressed as 1/[concentration]) and Os isotopes in rivers from around the globe (courtesy of B. Peucker-Ehrenbrink, WHOI). Os isotope composition of the Ganges at its outflow is the most radiogenic. *Peucker-Ehrenbrink, B.; Ravizza, G., The marine osmium isotope record, Terra Nova, October 2000, Vol. 12, Issue 5, p. 209, Figure 3; (AN 5311148)/ Reproduced with permission from Blackwell Publishing Ltd.*

In addition to the huge fluxes of water and sediment from the rivers, additional fluxes from submarine groundwater discharge (SGD) have been recognized at the river mouth. These fluxes augment the already high riverine fluxes of alkaline elements Sr, Ba, and Ra. The source of these elements appears to be the weathering of aquifer protolith as well as adsorption-desorption reactions with aquifer solids. It is likely that other elements are also affected by SGD. These may include rare earth elements and Os. Additionally, some elements, e.g. U, may be removed as sea water circulates through reducing zones in the aquifer. Thus, SGD may serve as source and sink with respect to TEIs.

The broad shelf region of the entire basin suggests that water-sediment interactions and SGD are important throughout the margin of the BoB. The SGD flux may be especially high on the east side as high hills rise sharply beyond the coastal zone.

Atmospheric deposition is one of the most dominant and effective means of delivering trace element and their isotopes (TEIs) to surface waters of interest to GEOTRACES. This is particularly the case in the Indian Ocean, where enclosed sub-basins to the north are located in close proximity to large arid areas of dust and large human populations with related industrial emissions located on the Indo-Asian sub-continent. This includes the Bay of Bengal (BoB), which is impacted by dust and other aerosol emissions from both the Indian subcontinent to the west and East Asian regions to the east. The aerosol content is particularly prevalent during the inter-monsoon winter period. At this time, the prevailing winds blow aerosols laden with both mineralogical trace elements (e.g. Fe and Al), and co-scavenged industrial trace elements (e.g. Zn, Pb, Cu, Cd, etc) of core interest to GEOTRACES.

The aerosol associations include emission of particles derived from combustion activities that also carry acidic species (Sarin et al., 1999). Evidence for this comes from previous data collected in the BoB, which shows the complete neutralization of acidic constituents (SO_4^{2-} and NO_3^-) by carbonate material (Figure 5; Rastogi and Sarin, 2006). This has the effect of shifting acidic emissions and associated TEI's from the fine to coarse mode that could accelerate dry deposition. The results of such atmospheric transformation processes suggest possible overestimation of climate cooling, as well as mobilization of essential micronutrients (e.g. Fe) from mineral aerosols to the surface ocean. During the southwest monsoon of the summer period, such acidic and emission aerosols might thus appear less because of the prevailing marine air, but rather due primarily to the extensive scavenging by wet deposition that should actually have more of a depositional impact on surface waters of the BoB.

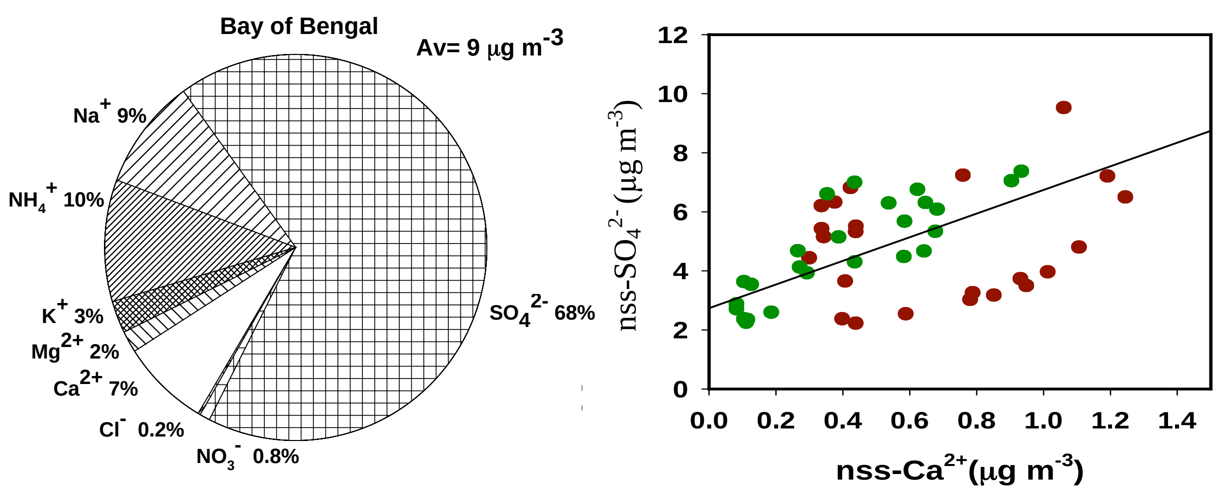


Figure 5. Bay of Bengal aerosol composition (M. M. Sarin, unpublished).
(A) Water soluble ionic species
(B) Neutralization of excess Ca^{2+} and SO_4^{2-}

4.2. Summary of previous biogeochemical studies in the Bay of Bengal:

- Aerosol measurements:
  - Water soluble ionic species
  - Carbonaceous aerosols
  - ^{7}Be, ^{210}Pb deposition flux

- Riverine flux of major ions, Sr, Re, Ba, Ra, U (from Ganga & Brahmaputra)

- Estuarine flux of major ions and uranium (from Hooghly & Godavari)

- Seawater measurements:
  - Export flux using U/Th series nuclides and ^{15}N as tracers
  - Ra isotopes for surface circulation
  - ^{14}C for circulation, air-sea CO_2 exchange, marine ^{14}C-reservoir ages
  - ^{10}Be (tracing inputs of fresh water and dust)
  - ^{32}Si (circulation)

- Sediment measurements:
  - Burial flux of trace & rare metals
  - Burial flux of organic carbon

4.3. Summary of Bay of Bengal Issues

River fluxes:
Fresh water influx is the most important external component in the BoB. In addition to the considerable buoyancy introduced to surface waters and to the dissolved load, the suspended sediments react with sea water to initiate desorption-adsorption reactions. The fresh waters contribute characteristic signals of stable isotopes of H and O. The input of materials from the Himalayas and other regions with their own signatures can be tracked by the analysis of stable isotopes in water and particulates such as C, N, O, Os, Sr, etc. Alkaline earths and REEs are also supply a source-specific signature.
In this region, nutrients and their cycling, and the influence of metal-organic interactions on them, are important.

Submarine Groundwater Discharge (SGD) fluxes:
There are clear SGD sources in the Ganga-Brahmaputra delta. It is likely that SGD fluxes are important along the east coast of India and west coast of Bangladesh. Many of the same components contributed by the rivers are also supplied by SGD, but the relative contributions are likely quite variable and in some cases opposite. For example some of the U supplied by the rivers is removed as sea water circulates through the aquifer. We expect SGD to contribute significant fluxes of alkaline earths (Sr, Ba, Ra), REE, Os, and nutrients.

Atmospheric input:
Perhaps the most important atmospheric input is rainfall that carries particles and aerosols and contributes buoyancy to surface waters. The region does not receive significant Saharan dust flux. However input of continental dust and of rainfall during the monsoon and under the influence of episodic events (cyclones, fires) requires further investigation. Anthropogenic inputs in the form of acid rain are significant.

Productivity controls:
Productivity is limited in this region by nutrient supply from river water, SGD and vertical mixing, N_2 fixing and the ballast effect that removes live biomass to the aphotic zone. In spite of the fact of low biological production and a less intense OMZ compared to the Arabian Sea, intense N_2O production occurs in the BoB shelf waters.

Indonesian throughflow:
The Indonesian Throughflow (ITF) represents a major element of global meridional overturning circulation, as warm surface water from the Pacific moves into the Indian Ocean. Part of the ITF water is influenced by sediment-water exchange reactions as it passes over the shallow shelf regions surrounding Indonesia and Southeast Asia. Sources and sinks of TEIs associated with these exchange processes should be quantified. Exchange of water across the Indonesian archipelago between the old Pacific waters and younger Indian Ocean water of different biogeochemical signatures can be constrained by stable isotopes (C, N, O) and radioactive isotopes (^{14}C, Ra)

Residence time of surface water:
The BoB is an integrating basin where concentrations are affected by external fluxes and internal recycling. A key parameter in evaluating these effects is the residence time of the surface water. Because of vertical stratification, the residence time of surface water is low, estimated to be ~5 years based on limited data of Tritium-^3He in upper 150 meters. Additional distributions of T-^3He and CFC, and ^{14}C need to be analyzed.

Deep sediment sources:
The Bengal submarine fan extends to 12^{o}S. The deposition of its sediments is modulated by the glacial-interglacial changes over the geological time scale. Paleo depositional and diagenetic proxies of productivity, climate, continental weathering, hydrothermal and geothermal inputs are traceable by the analysis of different inorganic and organic proxies.

4.4. Proposed Cruise Tracks and Justification

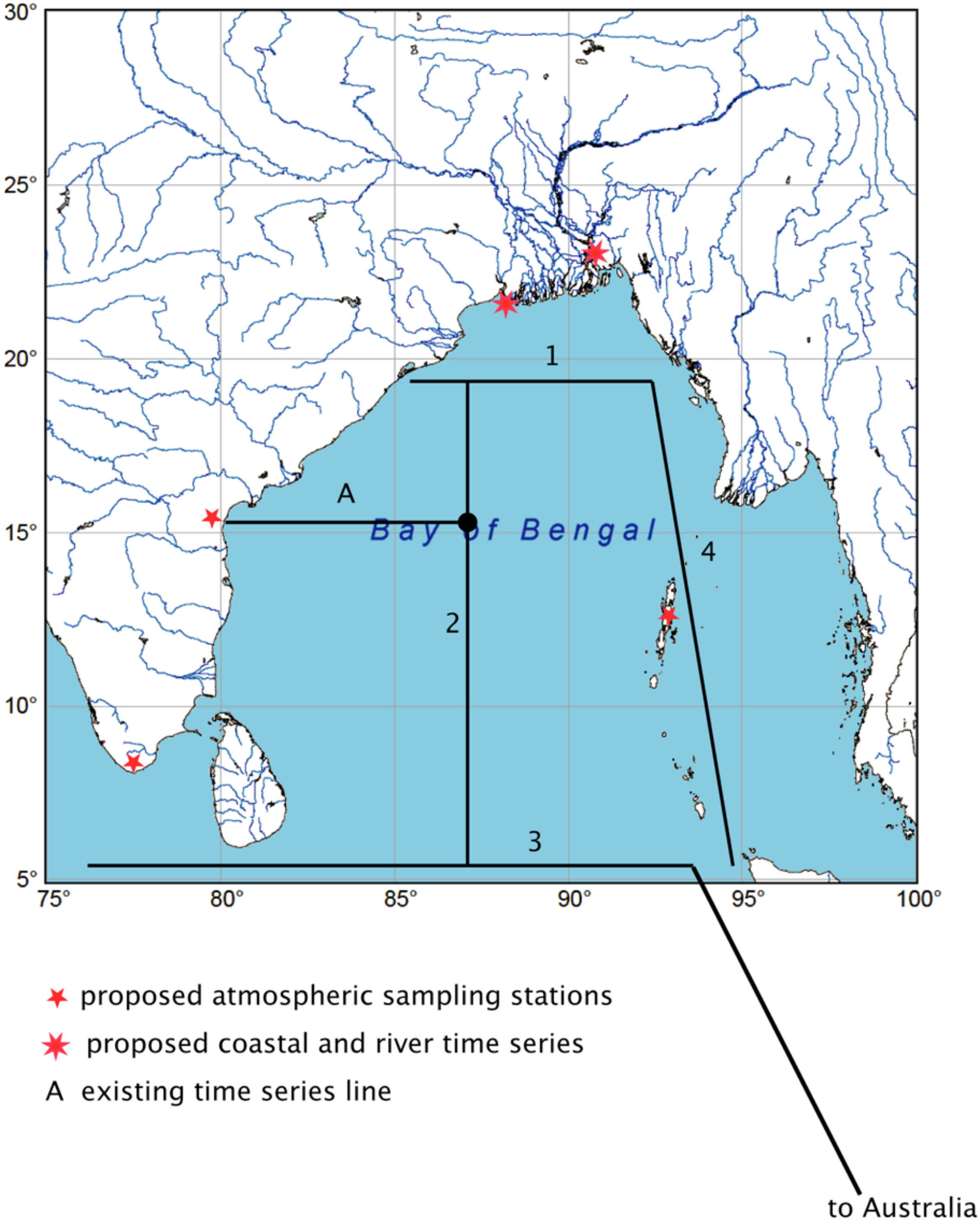


Figure 6. Proposed cruise tracks. The rationale for each section, along with information about existing and proposed time series sites, is provided in the text below.

Track 1: This track is a zonal section below the Ganges-Brahmaputra River mouth intended to cover high-resolution sampling as water and sediments fan out from the river to different regions of the BoB. This section will provide samples that represent the transformation of the riverine end-member by mixing with seawater, by sediment interactions, and by SGD input.

Track 2: This meridional section from the head of the BoB through the basin to the equatorial region is intended to provide samples to study transformations that occur during the passage of water across the Bengal fan into the deep equatorial region.

As a part of Bay of Bengal Process Study by the National Institute of Oceanography, studies were conducted along 90°E longitude. These limited studies indicated that nutrients delivered by rivers are consumed at the estuarine regions and that there is no supply of riverine nutrients to the sea. Also due to vertical stratification, the euphotic zone remains largely unproductive. The BoB is a net sink for atmospheric CO_2 except in summer. Upwelling is confined to the coastal regions during summer monsoon and its offshore extent is restricted by coastal circulation. Due to heavy riverine influx and the estuarine character of the BoB, the OC and its complexation to trace metals and nutrients with implications on TEI cycling have not been addressed so far. Track 2 along 85°E, which is 5° away from the 90°E ridge, is expected to be distant enough to not be affected by the aberrant water chemistry due to interaction with the ridge system.

Track 3: This zonal section traverses the widest region of the BoB. After crossing the BoB it turns southeast and connects to the NW coast of Australia. This section is intended to provide samples to (1) study the transformations that occur between the BoB and the equatorial Indian Ocean, (2) assess exchange between the BoB and Arabian Sea, and (3) determine fluxes into the Indian Ocean through the southern Indonesian Seas. On the seafloor, there are several seamounts where active volcanism has been reported.

The 2007 CLIVAR I8S/I9N cruise has identified a region of enhanced dust deposition to the surface ocean between 25 and 10˚S along 95˚E. The ultimate source of this mineral dust is believed to be the arid regions of Australia. It is suggested that a diversion at the end of the Bay of Bengal GEOTRACES Track 3 either to the east or the west of 95˚E between 10 and 25˚S could help delineate the areal extent of this feature and thus the significance of its input of continental materials to the surface waters of this region. Since the deposition signal is manifested in surface waters, the majority of the sampling to address this feature could be made using a surface towed sampling system, rather than vertical stations, thus minimizing the impact on available cruise sampling time.

Track 4: This track will provide samples from the northern region of Indonesian throughflow and also the major rivers, Irrawaddy and Salween. It crosses the Andaman backarc region, an active ridge system where hydrothermal inputs are expected. In the Andaman Sea, the mixing of water takes place only above 1800 m; the deeper water is stagnant. The northern half of the track falls within the EEZ of India.

Track A: This existing time series track will be occupied for at least the next 3 years.

Figure 6 shows three time-series stations, (i) coastal region of BoB off-shore of the Godavari river (Track A), (ii) the Hooghly River in India and (iii) the Padma River in the Bengladesh.

(i) Time-series sampling in the coastal region of the BoB off-shore of the Godavari River is already operational. It is being operated by

Dr. VVSS Sarma/Dr. Dileep Kumar
NIO Regional Centre,
176, Lawsons Bay Colony
Visakhapatnam - 530 017
India

Other two time series stations are for sampling the Ganges River in India and in Bangladesh. These are proposed stations.

(ii) The Hooghly river has been proposed by

Dr. Koushik Dutta
AMS Radiocarbon Laboratory
Institute of Physics
Sachivalaya Marg, P.O. Sainik School
Bhubaneswar - 751005, Orissa, India

(iii) The Padma river station in Bengladesh was proposed by

Dr. W.S. Moore
Dept. Geological Sciences
University of South Carolina
Columbia, SC 29208 USA

Atmospheric sampling sites, shown as smaller red stars in Figure 7, are discussed below.

4.5. Atmospheric Sampling Strategy

In order to capture the dominant record of atmospheric deposition to the BoB, both ships and land based sites will be necessary to establish the long term records. The core GEOTRACE collections are proposed to include both bulk and size differentiated aerosols, along with precipitation events encountered during proposed transects. However, as these collections will be limited in time and space to the cruises and their tracks, it is essential to supplement the BoB atmospheric collections with sustained land based sites. These sites should collect as minimum, weekly hi-volume aerosol samples using clean filters, with the sampling systems positioned and activated to collect aerosols from clean marine air coming from remote sectors. Ideally they should be interfaced with

CCN detectors to shut down operations during local ship passage upwind. They should be sites where meteorological observations are also being made (e.g. existing weather stations). When possible or during intensive studies, aerosol collections should be size segregated into fine, dust and coarse mode aerosols, which will help to inform models of dry deposition. Equally important is inclusion of wet deposition by the inclusion of wet activated precipitation samplers designed for clean TEI collection. These collections are particularly important during the seasonal monsoon rainy period, when most of the actual deposition is likely to occur. In addition, it is useful and rather easy to include bulk deposition to capture total deposition to ensure adequate depositional material for TEI analyses, particularly atmospheric stable isotopes and radionuclides. Together with wet deposition, this allows an assessment of dry deposition for comparison with that calculated from aerosols using dry deposition velocities.

Proposed Atmospheric Sampling Locations:

The four proposed cruise tracks (Figure 6) will encompass meridional and zonal transects along the length and breadth of the BoB where underway aerosol and precipitation collections are proposed as part of the core collections at sea. In addition, three land based sampling sites are proposed in the area. These included two on the coast of India (small red stars in Figure 6) at 1) Kanya Kumari on the south tip of India, 2) Yanam near the mouth of the Godavari estuary (NIO Regional Center, Visakhapatnam) and 3) at Port Blair on the Andaman Islands (cooperation with University of Pondicherry). Here both continuous aerosol and regular precipitation collections should occur, sustained over the years of GEOTRACES operation in the Indian Ocean.

4.6. Additional Implementation Issues

Prior Research:

A substantial body of research on TEIs in the Bay of Bengal has been produced by Japanese scientists (e.g., Alibo and Nozaki, 2004; Amakawa, et al., 2000; Nozaki and Alibo, 2003; Obata, et al., 2004; Okubo, et al., 2004). This work can be consulted as a resource when detailed plans are made for sections and process studies in the BoB.

International Partners:

Although unable to attend the planning workshop, GEOTRACES scientists in France expressed a strong interest in collaborating with colleagues from India and elsewhere in research on the Bay of Bengal. Interests and research objectives described below indicate a potentially significant contribution from France toward GEOTRACES research in the BoB. Contact information is provided below to facilitate collaboration as plans begin to evolve for specific sections.

French research interests can be divided into two categories:

<u>First category of objectives – Sources, sinks and internal cycling</u>

1) To understand and quantify how the water masses are modified after the contact with the margins and the river mouths (and how they have been modified in the past) within the energetic continent/ocean interface surrounding the BoB,

2) To trace the Himalayan weathering and its impact on the chemical composition of the neighboring ocean (present and past),
3) To contribute to tracer studies of ocean circulation in this area, in association with physical oceanographers.
4) To calibrate the behavior of paleo-circulation and paleo-weathering proxies.

To achieve these objectives it is proposed that trace elements (e.g., Al, Fe, REE, others…) and isotopes (Nd, Th, Pa, Ra, Hf, Pb) be measured in the water column (particle, dissolved), in surface sediments (multi-corers, selected sediment cores) and in authigenic and detrital phases.

Area of interest: Bay of Bengal
- from both east and west margin to the center of the Bay
- from the Ganges mouth to south of Sri Lanka.

Second category of objectives: hydrothermal fluxes
1) To trace the hydrothermal circulation in the oceanic floor and in marine sediments, and
2) To constrain the geometry of the fluid circulation: e.g., where are discharge/recharge areas and what is their intensity?

To achieve these objectives it is proposed to measure the chemical composition (Majors and Trace elements, Li isotopes, radiogenic isotopes) of hydrothermal fluids and interstitial waters.

Area of interest: Bay of Bengal
- With a specific attention to the margins, and
- in the southern parts, the flanks of the north Indian ridge

Proposed Framework for collaboration between France and India

French scientists have made very preliminary (but positive) contacts with colleagues of IRD (French Research Institute devoted to capacity building) and Indian Physical Oceanographers (P.O.) working in Goa. As a result of these contacts, it seems that the most interesting strategy should be to build a cooperation with Indian P.O. and geochemists, based on geochemical-physical coupling.

On the French side, interested researchers identified so far:

Toulouse
- C. Jeandel (CNRS) and team: seawater radionuclides and radiogenic isotopes
- C. Monnin and V. Chavagnac (CNRS): hydrothermalism tracers

Grenoble
- C. Chauvel (CNRS): radiogenic isotopes (Nd, Pb, Hf) in sediment

Orsay
- C. Colin (Univ Orsay): sediment cores, radiogenic isotopes, authigenic and detrital fractions

Paris

- CJ Allègre and L. Meynadier (Univ Paris VI): Sediment radiogenic isotopes (Sr, Nd…), authigenic and detrital fractions

Primary Contact: Catherine Jeandel Catherine.Jeandel@legos.obs-mip.fr

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5.0 Southern Ocean Working Group report

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R. Mohan and K. Pahnke, Co-Rapporteurs

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5.1. Introduction: problems, questions, processes

The objectives to be met by GEOTRACES in the Indian sector of the Southern Ocean are the characterization of the TEI distributions and gradients across the circum-Antarctic fronts at different longitudes. This will allow sampling of surface, intermediate and deep water masses that outcrop around Antarctica and hence enable the characterization of these water masses with respect to their TEI properties. Moreover, the in- and outflow of waters into and out of the Indian Ocean both zonally and meridionally were identified as important processes to be targeted by GEOTRACES to characterize marine input, loss and mixing of TEIs. Central regions in this respect are the southwest and southeast corners of the Indian Ocean, where water-mass exchange occurs with the Atlantic and Pacific Oceans (e.g., the "Tasman Leakage" of intermediate water south of Australia), and the subtropical Indian Ocean, where waters are exchanged between the Southern Ocean and the subtropical Indian Ocean (Figure 7). The Kerguelen and Crozet Islands are potentially large sources of TEIs to the ocean that need to be considered by GEOTRACES. Other important TEI sources to the southern Indian Ocean are small dust plumes from Africa and Australia (Figure 8), and hydrothermal fluids from the mid ocean ridge, where the largest fluxes are thought to occur at the Rodriguez Triple Junction.

5.2. Related Programs

Several programs are contributing to our understanding of the marine biogeochemical cycles of TEIs in the Indian Sector of the Southern Ocean, and these figured heavily in the deliberations of the working group.

Meridional sections to be carried out as part of the GEOTRACES contribution to the International Polar Year will constrain the transport of TEIs by the Antarctic

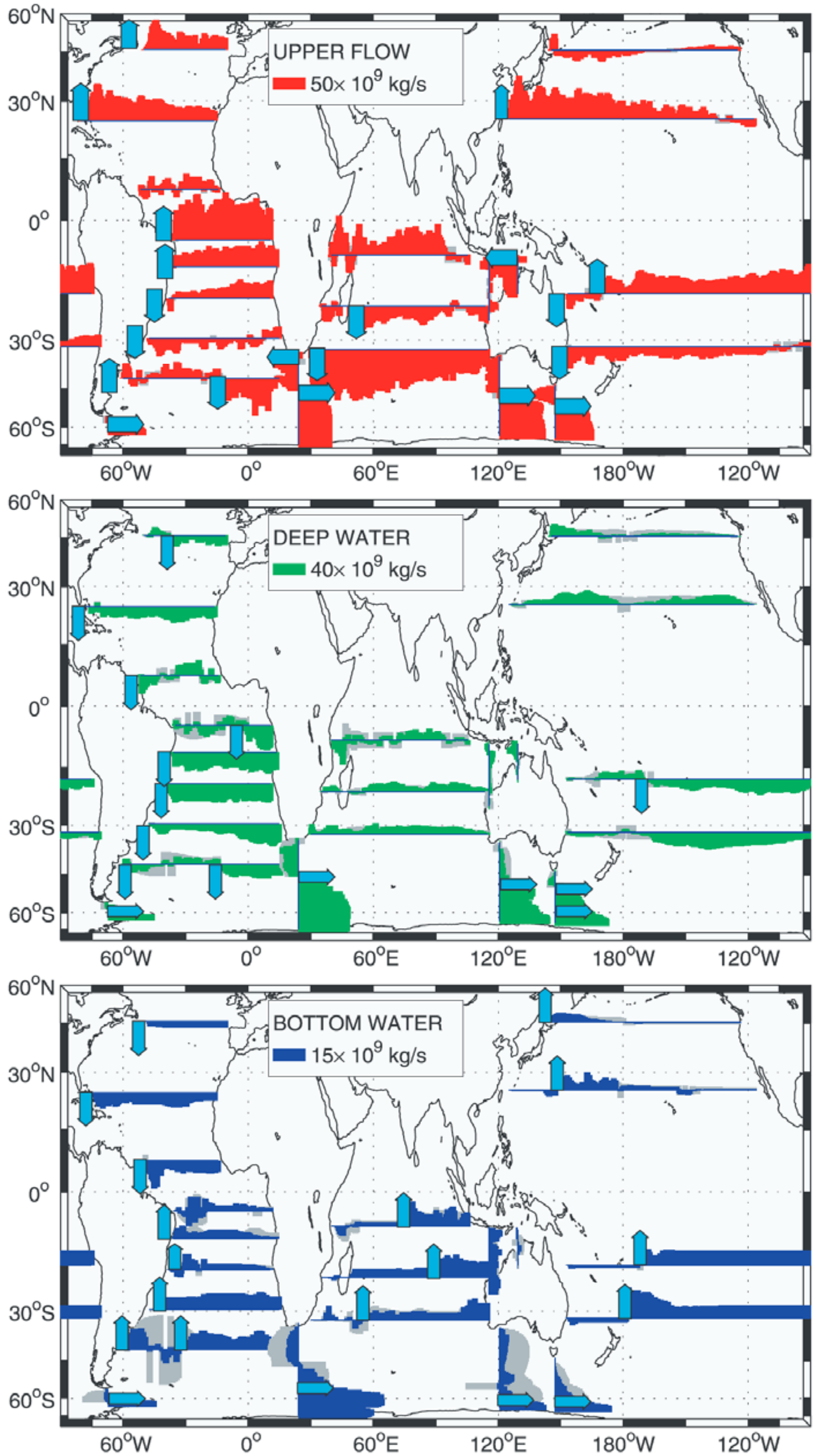

Figure 7: Horizontal flow of intermediate, deep and bottom waters (from Ganachaud, 2003). *Reproduced with permission from the American Geophysical Union.*

Circumpolar Current (ACC) into, and out of, the Indian Ocean (Figure 9). The international BONUS-GOOD HOPE program, led by France, will measure TEI distributions from South Africa into the Weddell Gyre. The BONUS-GOOD HOPE cruise will intersect the eastern meridional section of the international ZERO and DRAKE program aboard the Polarstern, thereby completing a section across the ACC south of Africa. In the east, Australian scientists will lead an international cruise along the WOCE SR3 repeat transect from Tasmania to Antarctica. Each of these expeditions is planned for austral summer 2007-2008, and the full suite of GEOTRACES key parameters will be measured along each section.

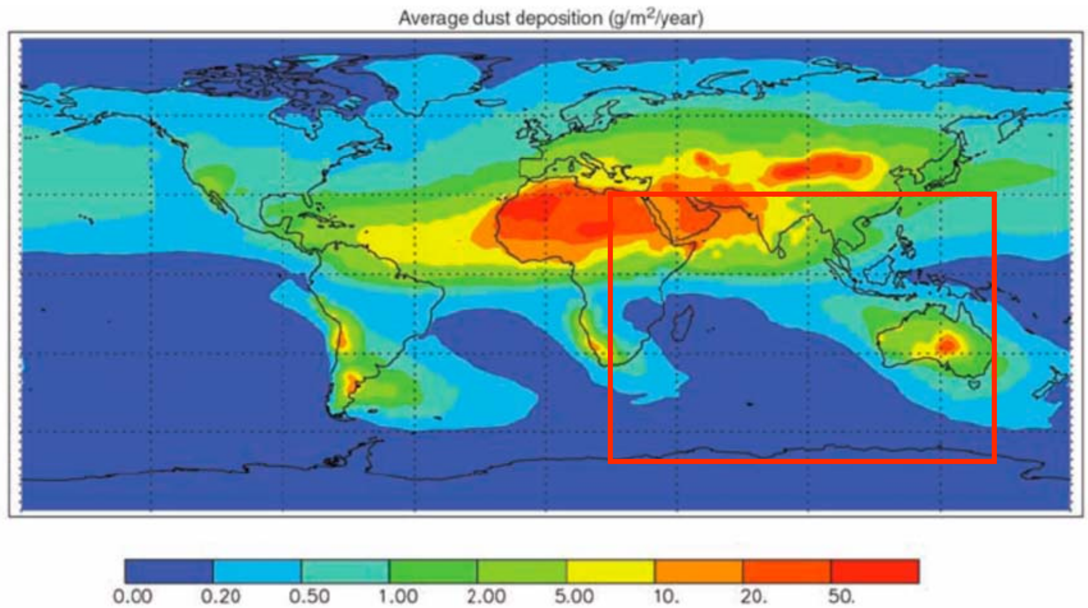

Figure 8: Dust fluxes to the global oceans in g/m^2/year (Jickells *et al.*, 2005). *Reproduced with permission from Science, http://www.sciencemag.org.*

Planned cruises of Japan and India offer additional opportunities for GEOTRACES work in the Southern Ocean. A Japanese cruise aboard the Hakuho Maru (Nov. 2008 – Feb. 2009) will sample for the full suite of GEOTRACES key TEIs at 10° spacing along meridional sections at 65°E and at 30°E (Figure 9). The complete section at 65°E, running from 20°N to 60°S, will cover a broad range of dust deposition regimes, providing a valuable measure of atmospheric TEI sources to the Indian Ocean. The southern end of the section, which will be associated with the IPY program conducted by the Polar Research Institute, Japan, will sample each of the principal water masses of the Southern Ocean.

The Southern Ocean program of the National Centre of Ocean and Antarctic Research (NCOAR) in India plans annual cruises from 2008 to 2010 that include meridional sections at 45°E and 57°E (Figure 9). Although these cruises were originally designed to address a number of other objectives, including marine geophysics, paleoclimatology, and biogeochemistry, there was a widespread interest among workshop participants to include TEI sampling during one of the later cruises in this series if clean sampling systems can be provided in time and scheduling permitting.

Recent process studies have examined sources of iron from islands located within the ACC, as well as the biological response, both in terms of changes in cell physiology and the impact on nutrient utilization and carbon export. Results from both the CROZEX (UK, Crozet Island) and KEOPS (France, Kerguelan Islands) programs showed clear evidence for stimulation of phytoplankton growth by iron released from the islands and their surrounding sediments.

Altogether, when fully synthesized, the results from the programs identified above will represent a substantial contribution toward our understanding of TEI biogeochemistry in the Indian Sector of the Southern Ocean. Specifically, these studies will establish:

1) TEI transport by the ACC at choke points south of Africa and Tasmania,
2) TEI distributions in each of the principal zones of the Southern Ocean, as delimited by the principal hydrographic fronts, and
3) The biological response to micronutrient supply from islands.

In addition, the Indian cruises are well positioned to quantify TEI transport into the Indian Ocean by North Atlantic Deep Water and by Antarctic Bottom Water, where these water masses flow around the deep topography south of Madagascar and into the SW Indian Ocean. There was extensive discussion of whether or not an additional section from Africa into the Southern Ocean would be needed to characterize these deep water masses. After examining WOCE sections of salinity and phosphorus at ~50°E, as well as published schematics of deep water flow into the Indian Ocean, the working group concluded that an additional section to sample these water masses is unnecessary. In light of the information summarized above, the working group recommends that a zonal section between South Africa and Australia would be of greater benefit to GEOTRACES than would be an additional cruise in the Indian sector of the Southern Ocean.

5.3. Proposed section and justification

Already realized or planned cruises in the Indian Ocean ensure extensive sampling across the circum-Antarctic fronts (see above). A number of objectives identified for the Indian sector of the Southern Ocean will therefore be addressed. A zonal section across the Indian Ocean near 30°S was discussed to characterize TEI exchange between the Southern Ocean and the Indian Ocean. The proposed section traces the WOCE and planned CLIVAR section I5, the latter of which is planned for 2010. It runs along ~30°S from South Africa to 30°S and 75°E, where it diverts from 30°S in a diagonal to ~25°S and 85°E to continue on a southwest track to Perth, Australia.

The proposed section will give insight into the exchange of intermediate, deep and bottom waters between the Southern Ocean and subtropical Indian Ocean. This is important with respect to Atlantic waters entering the Indian Ocean south of Africa and the transport of Southern Ocean water masses to the North. The proposed section will also provide an opportunity to quantify fluxes of TEIs into the Indian Ocean via the Tasman Leakage (Speich et al., 2002), a flow of intermediate water south of Australia. Prior studies of WOCE results along 30°S in the Indian Ocean have reported a substantial northward flow of deep water, and compensating return at intermediate depths (Figure 7). Following a similar approach, meridional fluxes of TEIs can be constructed. Documentation and ultimate quantification of the associated TEI fluxes is crucial for the closure of total TEI budgets and the identification of TEI sources and sinks in the Indian Ocean. The proposed section further crosses the dust plumes from Africa and Australia that were identified based on the global dust map of Jickells *et al*. (2005) (Figure 9).

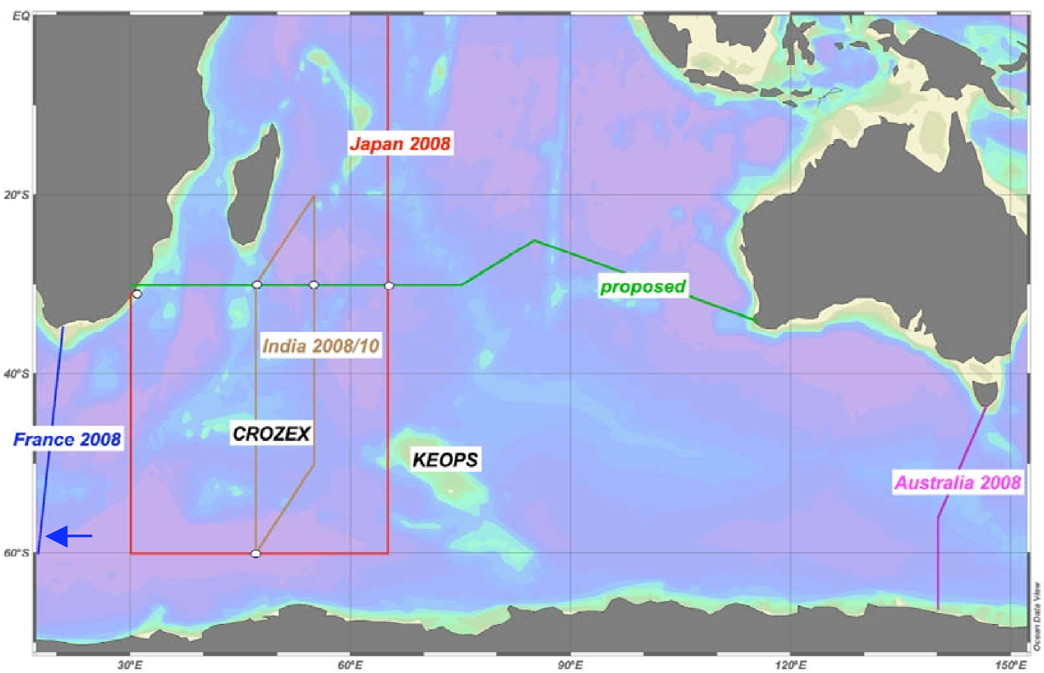

Figure 9: Antarctic and subtropical sectors of the Indian Ocean with planned and proposed (green) GEOTRACES sections. Previous process studies carried out under the French and British programs KEOPS and CROZEX, respectively, are marked, as are GEOTRACES IPY sections of France and Australia.

5.4. Implementation recommendations

While no nation volunteered to take the lead on the proposed section, three possibilities were identified: (1) a U.S. section, (2) a China section, and (3) a collaborative effort in which the U.S. and China each complete half the section. The U.S. and China each have interests that will bring a research vessel to the southern Indian Ocean. The COMRA program of China is interested in exploring mineral resources associated with hydrothermal systems along the mid ocean ridge in the western Indian Ocean. If China supports a research cruise to the Indian Ocean for COMRA, then it may be possible to add a leg for GEOTRACES along the proposed section. Scientists in China are already exploring possible collaboration between GEOTRACES and COMRA in the equatorial Pacific Ocean, and work in the Indian Ocean could build upon that effort.

The CLIVAR I5 section will be carried out aboard a U.S. vessel. Placing a U.S. vessel in the Indian Ocean is difficult because of the distance from the U.S., so there is often incentive to support multiple programs once a ship is in the region. Sampling for the complete suite of GEOTRACES TEIs along the I5 section would stretch the duration limits of a single cruise, so it may be advantageous for the U.S. and China to each complete part of the section.

Carrying out a GEOTRACES cruise back to back with a CLIVAR cruise has an additional advantage that the two programs require many of the sampling systems, particularly for nutrients and hydrography. In principle, these systems could be set up and shared by both programs, thereby facilitating logistics and reducing costs. The principal disadvantage of carrying out a GEOTRACES cruise back to back with the CLIVAR cruise is the timing. The CLIVAR cruise is planned for 2010, which is the earliest that U.S. GEOTRACES could mount a major section. If U.S. scientists wish to mount a GEOTRACES cruise back to back with the CLIVAR cruise in 2010, then planning must begin very soon.

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6.0 Summary

At the end of the three-day meeting an initial plan with cruise tracks and logic for each had been assembled (Figure 10), and countries were identified that would take the lead in trying to obtain logistical and financial support to implement the sections. In addition to planning strategies to achieve scientific objectives within each of the regions represented by the working groups, there were extensive discussions of four general topics: intercalibration, data management, Exclusive Economic Zones, and trace-metal clean sampling systems. These topics are discussed in Section 2.

Intercalibration was an ongoing activity of GEOTRACES at the time of the workshop (Appendix 3). Intercalibration, together with the introduction of trace metal clean sampling systems to nations surrounding the Indian Ocean, will serve as a significant contribution to capacity building in the region. It is recommended that GEOTRACES employ a dual strategy to foster trace metal clean sampling technology in the region. First, GEOTRACES scientists are encouraged to bring clean sampling systems into the Indian Ocean as participants in the research programs of nations of the region. There, local scientists can receive hands-on training in the deployment and recovery of the sampling systems, drawing and processing samples without contamination, and sample archival under contamination free environments. Second, GEOTRACES is encouraged to establish an international training center to which scientists from many nations can come for training.

Crossover stations, where cruises of different nations or involving different groups from the same nation overlap with one another, offer an opportunity for ongoing intercalibration, long after the formal GEOTRACES intercalibration effort is concluded. In some regions of the Indian Ocean, for example in the Arabian Sea, seasonal changes in forcing are so severe that variability may occur to depths as great as 1200 m. Nevertheless, TEI concentrations in deep waters are expected to remain relatively stable throughout the duration of the GEOTRACES program, and careful comparison of results from different cruises will serve as a valuable intercalibration strategy. Stations in the Arabian Sea along 65°E will be occupied by India, Japan and The Netherlands. Special care should be afforded to ensure that sampling strategies are designed with intercalibration in mind. Additional crossover stations in the Bay of Bengal (India, Japan) and in the subtropical Indian Ocean (30°S, 65°E; Japan, U.S.) will provide opportunities for bilateral intercalibration.

Hydrothermal Systems

Hydrothermal systems, and their associated TEI fluxes, were discussed in each working group. However, no working group developed explicit plans for the study of hydrothermal systems. Therefore, during the planning of appropriate section cruises, it is recommended that consideration be given to sampling around these regions to identify and quantify TEI sources and sinks. Special areas for investigation include the Rodriguez Triple Junction and the Andamann Sea.

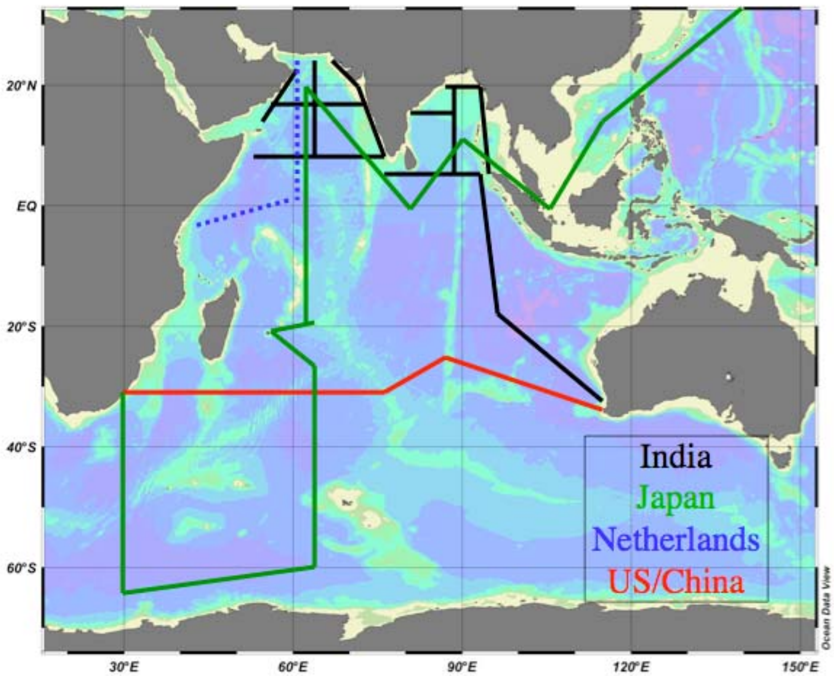

Figure 10. Summary of tracks proposed for GEOTRACES cruises in the Indian Ocean. Ship time for the Japanese GEOTRACES expedition in the Indian Ocean is already scheduled for November, 2008 – February, 2009. Rationale for cruise tracks identified as being led by India and US/China is provided in the working group reports above. Not shown here, but described in the Southern Ocean working group report, are sections south from Tasmania and from South Africa to be carried out as part of the International Polar Year by Australia and France, respectively. The cruise attributed to the Netherlands, at 60°E, is based on a proposal for a combined GEOTRACES – CARBOOCEAN study submitted to the workshop by Hein de Baar. Meridional sections in the Arabian Sea of India and Japan are both located at 65°E, although they are separated from one another in the figure for clarity.

7.0 Post Script

Recommendations from SSC Review: Barcelona, 4-6 November, 2007

1) That the Netherlands move its cruise track to overlap with the Indian and Japanese cruises so that an intercalibration station involving all three nations can be made,

2) That the Indonesian throughflow section and the 30°S zonal section be adjusted to have a crossover station,

3) That revisits to GEOSECS stations be made to expand the legacy of GEOSECS while also contributing to intercalibration and/or the study of long-term changes in the Indian Ocean,

4) That a section cross the Red Sea outflow to characterize TEI fluxes associated with Red Sea outflow water,

5) That seasonality be considered when developing cruise plans for sections around the margin of the Arabian Sea; although seasonality was mentioned in the workshop report, it was not clear that it was considered in planning the sections around the margin of the Arabian Sea,

6) That India acquire a clean sampling system, and individuals on the SSC work with Indian scientists to help them develop independent capability to use the clean sampling system. The SSC Co-Chairs are authorized to write a letter of support on behalf of the SSC.

7) That when a team is set up to develop the eastern meridional section, the team reconsider the optimum location of the section; e.g., maybe move it to the east to get a stronger signal of TEI fluxes through the Indonesian Throughflow, and

8) That another meridional section be added in the Southern Indian Ocean with higher resolution station spacing than offered by the Japanese cruise. The Dutch cruise will provide high sampling resolution in the northern Indian Ocean, and it would be valuable to add a high-resolution section to the southern Indian Ocean, perhaps carrying on from the terminus of the Dutch cruise. This could be considered a target for implementation in the latter part of GEOTRACES.

Appendix 1. Final Agenda.

INDIAN OCEAN PLANNING WORKSHOP

GOA OCTOBER 24-26 2007

Date		
23/10/07		
18:00-19:30	Registration	
19:30	Welcome Dinner	At the International Centre
24/10/07		
09:00-09:05	Sunil K. Singh	Welcome
9:05-09:15	Rasik Ravindra, Director, NCAOR	Inaugural Lecture
09:15-09:50	Bob Anderson, LDEO	Introduction to the GEOTRACES programme and the goals of the workshop
09:50-10:00	D.V. Borole, NIO	Vote of thanks
10:00-10:30	Tea/Coffee Break	
10:30-11:00	D. Shankar, NIO	Dynamics of large scale wind driven circulation off the Indian coast
11:00-11:30	Jim Moffet, USC	GEOTRACES and the Arabian Sea – A focus on the N cycle
11:30-12:00	M.M. Sarin, PRL	Atmospheric dust and anthropogenic trace element inputs to the tropical Indian Ocean
		Planned National Programmes
12:00-12:30	M. Sudhakar, NCAOR	India's Southern Ocean Programme: retrospect and prospect
12:30-13:00	T. Gamo, U Tokyo	Japanese Programme in the Indian Ocean
13:00-14:00	Lunch	At the International Centre
14:00-14:30	VVSS Sarma, Vishakhapattanam	Triple oxygen isotopes of dissolved oxygen as a tracer of biological processes
14:30-15:00	Dileep Kumar, NIO	IGBP Programmes in the Indian Ocean
15:00-15:30	Jim Moffet, USC	SIBER
15:30-16:00	Advocacy Talks	
16:00-16:30	Tea/Coffee Break	
16:30-18:30	Advocacy Talks	
20:00-	Conference Dinner	Ciudad de Goa

25/10/07		
09:00-09:30	Chris Measures, Univ. Hawaii	Data management
09:30-10:00	Rob Sherrel, Rutgers	Intercalibration
10:00-10:30	Tea/coffee Break	
10:30-11:30	Plenary	Finish advocacy talks and general discussion of them
11:30-12:30	Plenary	Plan formation of working groups
12:30-13:00	WG discussions	
13:00-14:00	Lunch	At the international Centre
14:00-16:30	WG discussions	
16:30-17:00	Tea/coffee Break	
17:00-17:20	Plenary	WG1 Reporting
17:20-17:40	Plenary	WG2 Reporting
17:40-18:00	Plenary	WG3 Reporting
18:00-18:30	Plenary	Discussion of data policy and EEZ restrictions
20:00	Dinner	At the international Centre
26/10/07		
09:00-09:30	Plenary	Discussion of data policy and clean sampling systems
09:30-10:00	Plenary	Further discussion of WG reports
10:00-10:30	Tea/coffee Break	
10:30-13:00	WG discussions	Revise plans and recommendations
13:00-14:00	Lunch	At the international Centre
14:00-15:00	Plenary	Presentation and discussion of revised WG reports
15:00-18:30		Report writing
20:00	Dinner	At the international Centre

Appendix 2A. Participants from institutions in India.

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Appendix 2B. Participants from institutions outside India.

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20	Robert Anderson	boba@ldeo.columbia.edu	United States

Appendix 3. Intercalibration groups and contact information.

1) Dissolved and particulate sampling systems, "core" trace elements – G. Cutter, K. Bruland, and R. Sherrell; gcutter@odu.edu
2) Si isotopes - Mark Brzezinski, brzezins@lifesci.ucsb.edu
3) N isotopes– Karen Casciotti, kcasciotti@whoi.edu
4) P (oxygen isotopes) – Albert Colman, colman@umbi.umd.edu
5) Hg – Carl Lamborg, clamborg@whoi.edu
6) Trace element stable isotopes – Ed Boyle, eaboyle@mit.edu
7) REE concentrations; Nd and Hf isotopes – Tina van de Flierdt, tina@ldeo.columbia.edu
8) Os isotopes - Bernhard Peucker-Ehrenbrink, behrenbrink@whoi.edu
9) ^{230}Th, ^{231}Pa, ^{10}Be - Bob Anderson, boba@ldeo.columbia.edu, and Brad Moran, moran@gso.uri.edu
10) Ra isotopes (and ^{227}Ac?) – Billy Moore, moore@geol.sc.edu
11) Pu isotopes and ^{137}Cs - Tim Kenna, tkenna@ldeo.columbia.edu
12) ^{210}Pb, ^{210}Po, and ^{7}Be – Mark Baskaran, ag4231@wayne.edu
13) Aerosols - Bill Landing, wlanding@fsu.edu
14) Fe (and other) speciation - Jim Moffett, jmoffett@usc.edu
15) Particulate ^{234}Th - Ken Buesseler, kbuesseler@whoi.edu

Appendix 4. Written summaries of presentations, including advocacy talks, to be submitted to the Indian Journal of Marine Science.

Provided by Mark Baskaran

Sl No.	Paticipant's Name	Tentative Title
1	Chris Measures	Results of JGOFS and CLIVAR and implications for renewed work in the Indian Ocean
2	P M Mohan	Advances studies of Geotraces in and around Andaman and Nicobar island seas.
3	M Baskaran	Monsoon-driven changes in the cycling and export fluxes of POC using $^{210}Po/^{210}Pb$ and ^{234}Th as tracers
4	Rob Shrell	Short piece about approaches to Geotraces intercalibration
5	A Okubo	Particle flux in the eastern Indian Ocean
6	T Gamo	Submarine hydrothermal activity in the Indian Ocean.
7	N Sarma	Biotraces in the Bay of Bengal
8	W Jenkins	Results from numerous WOCE cruises with ^{3}H-^{3}He measurements.
9	D Borole	Radiogeochemical and geochemical studies of the particles collected by time series sediment traps from the Arbian sea.
10	Rahul Mohan	India's southern ocean programme retrospects and prospects.
11	B Manjunathan	Importance of atmospheric inputs for primary productivity of South-western continental margin of India
12	Ch Sujatha	Biogechemistry and sediment dynamics of the estuarine and coastal waters along SW coast of Lakshadeep sea.
13	A C Narayan	1. Southern ocean programme
14		2. Monsoon-driven changes TEs variability and isotopes
15	P D Naidu	Role of ^{12}C fixation by various phyto plankton groups in the Arbian sea.
16	Sunil K Singh	Riverine fluxes of some of trace elements to the Bay of Bengal.
17	B Nagendra Nath	Deciphering the Hf isotopic signature of seawater from the authigenic fraction of the sediments.
	M Sudhakar	**To be determined**
	N Anilkumar	**To be determined**