# A White paper
# On planned activities of CORAL
# As of August 15, 2005

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## Executive Summary

An innovative **C**enter for **O**ceans, **R**ivers, **A**tmosphere and **L**and Sciences (CORAL) has recently been established at the Indian Institute of Technology, Kharagpur, a premier institution of national importance and of international stature. The Centre (CORAL) has been designed to carry out collaborative research and teaching with the University of Massachusetts at Dartmouth, USA and with other departments at IITKGP, aiming at bringing several new research areas related to **natural hazards** under one umbrella of this new centre. The efforts by the ex-alumni of IIT Kharagpur working at various Institutions in USA and abroad had been a major driving force and source of inspiration in setting up this newly formed center.

This White paper describes the research projects identified during a two-day kick-off meeting during July 18-19, 2005. Detailed scientific discussions led us to identify a series of six projects which will be used to form a comprehensive funding proposal. The list of attendees, agenda, detail minutes of the meeting, possible funding sources and newspaper clippings are attached in this document for completeness.

## Meeting Summary

During July 18-19, 2005, scientists from IITKGP under the leadership of Professor Shishir K. Dube and experts from US (Professor Avijit Gangopadhyay from University of Massachusetts, Dartmouth and Dr. Ramesh Natarajan form IBM, New York) and Canada (well known Tsunami expert, Dr. Tad Murty, and Policy expert, Dr. Ravi Seethapathy) were engaged in shaping the seeds of CORAL. Invited local participants include Professor Anandadeb Muhopadhyay of Digha Development Board, Prof. Sugato Hazra, and Professor Somnath Bhattacharya of Jadavpur University. Other eminent scientists included Professor Debasis Sengupta from IISc Bangalore, Dr. A. Narain from ISRO, Dr. A.D. Rao from IIT Delhi and Professor D. Sen from IIT KGP. Dr. Arindam Mitra of Indo-US forum was also present in the meeting which might provide critical support for CORAL's collaborative activities. A list of participants is attached in Appendix 1.

The meeting was subdivided into various sessions focusing on Oceans, Rivers, Atmosphere and Land related issues of national and regional context. Discussion on these four theme sessions were centered on a number of common sub-issues, which are the scientific processes, numerical models, observational network, warning systems, mitigation aspects, public education and socio-economic aspects. The agenda for the

meeting is shown in Appendix 2. Detail minutes of the meeting is provided in Appendix 3 (parts 1 and 2).

Several projects of **national relevance** of societal importance are being undertaken by CORAL in the near future. First of all, development of a travel time atlas for a Tsunami Warning System is under progress which will be very valuable all major coastal cities in all countries around the Indian Ocean. Second, a major focus of CORAL's activity will be on mitigation of post-hazard management. One need to appreciate that there are different kinds of natural hazards, their after-effects are different from each other and each hazard is very expensive (Central Govt. has released 500 Crores already for the victims of the recent Gujarat flood). CORAL will carry out a pilot project of studying the socio-economic impact of four particular cases: the Bhuj Earthquake, the Orissa Cyclone, the Tsunami of 2004 and the floods of 1978. This analysis will allow CORAL scientists to develop a unified strategy for future hazard mitigation practices. Another major focus will be to develop high-resolution three-dimensional Cyclone, storm surge and wave forecasting models which will be used for prediction of these seasonal disasters every year. An underlying theme is the development of a regional weather and ocean forecasting system to benefit the local population, commerce and industry. These projects will be carried out by IITKGP in collaboration with Tsunami experts from Canada (Professor Tad Murty), Oceanographers from US and elsewhere (Professor Avijit Gangopadhyay of UMass Dartmouth and his international colleagues), Computer experts from IBM, New York and others around the Country including IISC, IIT Delhi and ISRO.

A major thrust of CORAL is its intended involvement with the societal problems in **local areas** of West Bengal, Orissa, AP and other northeastern states. IITKGP is making sure that its expertise is used to address the problems of the regional nature. Four distinct areas of research have been identified. First, the rapid coastal erosion problems along the shores of eastern India (Digha to Sunderbans) will be mapped and zoned for erosion rates to aide development of resorts. Second, new technological designs and construction of coastal embankments will be provided from CORAL. Third, development of a system for modeling and monitoring the river floods in north and central Bengal regions is being undertaken. Finally, a recent interest on Thunderstorm Research (Kaal-Baishakhi forecasting) is also being considered. Some of these problems will be done in collaboration with Jadavpur University, ISRO and foreign experts from US and Canada.

## Research Projects for CORAL in the near future

Six major projects will be synthesized in one comprehensive proposal, which will be submitted to ISRO for possible funding.

1. River flow and flood modeling for the northeastern India – This study will be led by Dr. Dhrubo Jyoti Sen of Civil Engg. IIT-KGP, and strongly collaborated with Dr. A. Narain (ISRO), Dr. D. Sengupta (IISc), Dr. Tad Murty (University of Ottawa, Canada) and the group at Jadavpur University (Prof. Sugato Hazra and Dr. Somnath Bhattacharya). Three aspects of research were identified: flood inundation, riverbed size evolution and riverbank migration. In addition to

collaborating with ISRO and NRSA (to utilize satellite data), capabilities and expertise at the Dartmouth Center for Flood (in New Hampshire, MA) will be sought after for new technologies related to satellite river gauging.

2. Preparing a Tsunami Atlas, developing a Tsunami propagation model and implementing a Coastal Inundation model for the eastern coast of India. – This study will be led by Dr. Prasad Bhaskaran (OENA, IIT-KGP) and supported by Dr. Tad Murty in Canada and Dr. Gangopadhyay's group in UMass Dartmouth. This research will aim in the implementation and validation of a numerical model on tsunami generation and propagation in the Indian Ocean. Research will focus on the development of a coupled modeling system for tsunami generation and propagation in the Indian Ocean using existing space based technology. Considerable work had already been carried out on developing a scenario based approach with tsunami travel time estimates computed for 250 locations in the Indian Ocean basins. The deliverables (sea surface elevation) from numerical modeling together with travel time estimates will serve as the building blocks of a future Tsunami warning system for the Indian Ocean. The expected outcome of this work would focus on significantly reducing the response time for early warnings to South Asian countries by pre-computing the net surge of water levels on account of future tsunamis. Simulation studies will be carried out using information from past tsunamis of varying magnitudes. The results will be compiled as a comprehensive database with net surges (maximum possible tsunami amplitudes and horizontal extent of coastal inundation) at various coastal stations grouped by cluster of Southeast Asian countries. Further analyses and coastal inundation modeling efforts will follow.
3. A high-resolution ocean modeling program in the Bay of Bengal will be initiated by CORAL. This work will be led by Dr. Hari Warrior at KGP with support from Dr. Gangopadhyay (UMass Dartmouth), Harvard University and other interested national and international groups.
4. The coastal erosion problem along the northeastern coastline. – This study will be led by faculty in KGP (Drs. A. Bhar and T. Sahoo) in close association with Dr. Anandadeb Mukhopadhyay's group at the Digha Development Board and the group in Jadavpur University. A coastal inundation model (with help and guidance from Dr. Tad Murty) will need to be implemented; however, a massive high-resolution (0.5m vertical resolution at 5m x 5m horizontal grid) topographic mapping is necessary before an erosion monitoring program can become functional. Furthermore, a systematic evaluation of risk and assessment of reliability of coastal structures exposed to cyclones and floods will be carried out to recommend future design of safe and reliable coastal embankment structures. This study will suggest remedies for erecting new types of sea walls and /or breakwaters suitable for high erosion-rate coastal zones.
5. A regional atmospheric modeling program will be set up to aide in Cyclone and Thunderstorm research. The present MM5 configuration run by Dr. Chandrashekharan is at 20km resolution is too coarse to properly resolve and track the typical cyclones over the Bay. The proposed high-resolution modeling activity will require multiple processors and high-end visualization machines. Dr. Ramesh Natarajan of IBM, New York had indicated that an IBM SUR grant will

be submitted to help support such a computing and visualization effort for CORAL and other related activities at IIT-KGP.

6. A comprehensive earthquake microzonation effort will be undertaken as part of the Land-based initiative of CORAL for the states of Orissa and West Bengal. Two separate projects for the two states are already being discussed with relevant state agencies by Prof. Shankar Nath and Prof. S. Tripathy and Prof. Dube. These funding opportunities will be investigated further to be done collaboratively between CORAL and the Department of Geology and Geophysics.

These six projects are the initial milestone projects for CORAL. The group at large decided to put forward a Single comprehensive proposal to ISRO for funding to the tune of Rs. 2-10 crores (to be determined by Dr. Narain) with 4-6 major components as outlined above. The river floods, coastal erosion, tsunami propagation and atmospheric modeling seemed like a natural first choice of components.

**Funding and Support Opportunities**

The group discussed at length typical funding opportunities. A list of possible funding sources for different proposed efforts is listed in Appendix 4. In addition to ISRO and other national sources for funding, international agencies such as UNESCO, UNDP and other foundations will be contacted for possible funding sources.

In addition, Professor Dube has kindly initiated infrastructural support for five faculty members and a building in the near future. The CORAL building will house a war room (with high-tech visualization equipments in virtual reality mode (RVN from IBM)) and an Oceanographic Museum in the ground floor with a large seminar/conference room with distance-learning facilities. The first floor will house typical faculty offices and student/researchers work spaces with computers. The first floor spaces can follow the layout in the computing Laboratory of Dr. A.D. Rao in IIT Delhi at a larger scale. The whole CORAL building will be centrally air-conditioned with double–door at the entrance to minimize dust intake.

**Present Structure of CORAL**

*Head:* Dr. Subhashis Tripathy of Department of Geology and Geophysics will be heading the Center till a permanent head has been appointed.

*Faculty:* In the near future, five more faculty positions will be advertised and filled by end of January, 2006. The level of appointment will be open from Assistant to Full Professor level. The expertise for four of them will be primarily in Oceans, Rivers, Atmosphere and Land areas, supplemented by another faculty in Policy/Management/Disaster Mitigation area.

*Program Development:* PhD to start right away (2005). MSc (Research) will begin as soon as possible. M. Tech. program will require course offerings and thus will have to wait till the five new faculty have started.

## Outreach and Awareness of CORAL

A number of newspapers carried informative articles about CORAL during the week of July 18th, 2005. These included the Indian Express, the Times of India, the Business Standards, the Anandabzar Patrika (Bengali), Bartaman (Bengali), Kharagpur Jagaran (Hindi) and Pravat Sambad (Hindi). The English clippings are attached herewith in Appendix 6.

## Peripheral meetings attended by some participants with Govt of India officials

1. On July 22nd 2005, Drs. Tad Murty, Ravi Seethapathy and A.D. Rao met with Dr. Abdul Kalaam, the President of India, discussed Tsunami related research and informed him about CORAL.
2. On July 23rd 2005, Dr. Tad Murty, Ravi Seethapathy and A.D. Rao met with the Secretary, Department of Ocean Development (DOD) and apprised him of CORAL.
3. On July 25th 2005, Dr. Avijit Gangopadhyay met with Dr. A. Mitra, Director of Indo-US Forum to discuss proposal submission to the Forum for CORAL related activities. Dr. Mitra suggested that Dr. Gangopadhyay could come to the upcoming Indo-US summit in October 2005 in MIT and present CORAL's activities and promises as a Indo-US Center. The next call for proposals will be out sometime in November, 2005.
4. On July 26th 2005, Dr. Gangopadhyay met with Dr. Goyal, Secretary of the DOD for a brief meeting at 5pm. The Secretary committed to the support of CORAL and indicated that from a DOD perspective, CORAL should strive for providing solutions of problems. DOD will look forward to implementing such solutions for the benefit of the society. So, CORAL should not stop at analyzing the problems – it must strive to indicate possible solutions in the Indian framework. DOD will support CORAL in three aspects of directions for the future: Science, Technology and Services.

## Appendix I

List of Invitees and Attendees for the CORAL Kick-off meeting at IIT Kharagpur during 18-20 July 2005.

| Name | Institution | Expertise |
|---|---|---|
| | | |
| Bhar, Ashoke | IITKGP-OENA | Ocean Engineering |
| Bhaskaran, Prasad | IITKGP-OENA | Wave Modeling, Tsunami |
| Bhattacharya, Somenath | IESWM, Kolkata | Coastal Zone Management |
| Chandrasekharan, A. | IITKGP-Phy | Atmospheric modeling |
| Dube, Shishir | IIT KGP-Director | Storm Surge |
| Gangopadhyay, Avijit | UMass Dartmouth, MA | Ocean Modeling |
| Hazra, S. | Jadavpur University | Head, Oceanography |
| Mitra, Arabinda | Indo-US Forum | Oceanography |
| Mukherjee, C. | IITKGP- AgE | Fisheries |
| Mukhopadhyay, Anandadeb | Digha Dev. Board, Chair | Coastal Oceanography |
| Murty, Tad | U of Ottawa, Canada | Tsunami Warning System |
| Narain, Aishwarya | ISRO, SAC, Ahmedabad | Disaster Management |
| Natarajan, Ramesh | IBM, New York, USA | Computation, IT applications |
| | | |
| Nath, Shankar Kumar/ Tripathy, S. | IITKGP-Geology and Geophysics | Geology, Land and Geophysics |
| Seethapathy, Ravi | Indo-Shastri Institute, Canada | Societal/Public Rel, Tech. Platforms, Systems Integration, Outreach, Policy |
| Rao, A.D. | IITD – CAS | Modeling |
| Sahoo, T. | IITKGP | Coastal Zone Management |
| Sen, D.J. | IITKGP –Civil | River modeling |
| Sen, Debabrata | IITKGP-OENA | Hydrodynamics |
| Sengupta, Debasis | IISc, Bangalore | Bay of Bengal – Data/Models |
| Warrior, H. | IITKGP-OENA | Circulation |
| | | |

# Appendix II

## Agenda for the CORAL Kick-Off meeting at IIT KGP on July 18-19, 2005.

| Day | Morning Session 1 (10am-11:30am) | Morning Session 2 (11:30am-1:00pm) | Afternoon Session 1 (2:00pm - 3:30pm) | Afternoon Session 2 (3:30pm -5pm) |
|---|---|---|---|---|
| Day 1 Monday, July 18,2005 | Opening remarks by Shishir and Avijit;<br><br>**Self-Introduction by Participants** | Natural hazards in the Indian **Ocean**(Storm surges, tsunamis, wind waves, freak waves, submarine landslides) | **Atmospheric** hazards(cyclones, monsoons, droughts, meso-scale systems) | **Land** based hazards(Earthquakes, landslides, coastal erosion) |
| | | | | |
| Day 2 Tuesday, July 19, 2005 | **River** hazards(floods, siltation problems, hazards to navigation) | MTech and PhD programs, short-term courses | Funding, Projects, Resources, Computers, Strategic Planning | Wrap-up Recommendations Time-lines and Schedules |

Coffee Breaks: During the meeting Coffee and snacks will be provided intermittently.
Lunch will be available between 12:15pm and 1:30pm.

ALL FOUR THEME sessions on Ocean, Atmosphere, Land and Rivers will need to discuss the following sub-topics:
--- Scientific processes
--- Numerical models
--- Observational network
--- Warning systems
--- Mitigation aspects
--- Public education
--- Socio-economic aspects

Rapporteurs: Dr. Prasad Bhaskaran, Dr. Ashoke Bhar and Dr. T. Sahoo.

# Appendix III

**Part I: Minutes of the CORAL Brain-Storming meeting at Board Room, IIT-Kharagpur on July 18-19, 2005 (First day).**

During the meeting on 18 July, 2005 there were detailed discussions on seven important sub-topics covering areas on Oceans, Atmosphere, Land and River Sciences. These included discussions on scientific processes, numerical models, observational network, warning systems, mitigation aspects, public education and socio-economic aspects.

- For the study on tsunami generation and propagation, Indian Ocean region is quite unique compared to the Pacific. The reason being basin scale phenomena with many sub-grid features like islands etc., where reflected waves play an important role. Hence the selection of an appropriate grid resolution along both horizontal and vertical direction is crucial for computational studies and later inferences. As of today, grid resolutions of 2.5 m along X and Y and 20 m along Z direction is already available. These databases are available at the Survey of India. It has been realized in this meeting, that vertical resolution of 20 m (available today) is too coarse while dealing with coastal inundation problems, a resolution of 0.5 m will be quite ideal for computational purposes. Also, the States of Orissa and Andhra Pradesh have vertical resolution of 1.0 m which was compiled by the Survey of India.

- To address coastal inundation during an energetic event like tsunami, employing high resolution grids (say 1.0 m vertical res.) is a computationally intensive task which require high speed computing resources. The IBM can help in meeting the demands of computational resources available for CORAL. Likewise, it was decided choosing an appropriate resolution of (5m X 5m X 0.5m) would be ideal for addressing coastal inundation problems.

- Two copies of mini-atlas on tsunami travel time (TTT) had been distributed to participants in this meeting. As a first step dealing with natural disaster like tsunami, it was decided to prepare a comprehensive atlas on TTT covering about 250 locations surrounding the Indian Ocean rim. This atlas and relevant documentation will be made ready by the last week of August, 2005. Dr. Prasad Bhaskaran of OENA, IIT-Kgp will take the lead role in developing this comprehensive atlas for the Indian Ocean. The work on preparing TTT has been given priority during this meeting.

- It was discussed the existing tide gauges needs to be upgraded from what it is at present. This means, the existing tide gauges have a limit, which cannot detect signals beyond a threshold limit. Knowledge on cutting edge technology from scientists of electronics and electrical technology needs to be gathered on improving the present state of existing tide gauges in Indian Ocean. As tide gauges are the backbone, to disseminate valuable information on event of an extreme event viz; storm surges, tsunami etc; if these instruments can be calibrated to a higher scale to capture signals

of these extreme events, it will be a real valuable information. To accomplish this, relations need to be established with the people from Survey of India.

- Importance in tapping and exploitation of coastal resources and its relevance had been identified to be worked out at AgFE Department at IIT-Kgp.

- Problems related to coastal erosion and embayment had been addressed by the team from Jadavpur University (JU). The source behind extensive coastal erosion is yet to be identified and studied through numerical models. It could be understood from discussions with team from JU that extensive amount of land loss occurs in the northern part of West Bengal. Dr. Murty pointed out the possibility of convergence in wave energy to be an important factor which needs to be investigated as early as possible. It was also identified JU can have strong collaboration with OENA, IIT-Kgp to understand and investigate this problem through numerical modeling approach. Dr. Murty and Dr. Narain will take lead in this topic.

- The problem of river flooding is a major issue in West Bengal. The problem was identified and a remedial solution needs to be ascertained at the earliest. CORAL can take up research activities to study river flooding. Rivers like Tiesta, Rup Narain causes major flooding, hence depending on the water level at Farakka Dam, the discharge is diverted to Bangladesh. Modeling strategy needs to be started from grass root level as nothing much has been done in this context so far. Contacts from IIT Gowhati can be helpful. It was identified expertise of Dr. Goswami from IIT-Guwhati who works on remote sensing applications can be leveraged.

- It was understood there are agencies within India who can support for funding to study the flooding issues and source for possible mitigation. Some of the agencies identified are: (i) National Water Conservation Authority (ii) ISRO (iii) Ministry of Environment and Forest, and (iv) Ministry of Home Affairs. It could be known the studies using Synthetic Aperture Radar (SAR) system from SAC, ISRO Ahmedabad would be immensely beneficial; and which deals with disaster management affairs in India. As there are existing technologies and numerical modeling components available and already conducted in some places at US, it would be wise if SAC, JU and IIT-Kgp will get together and look how collaboration can be established with US based Universities to adapt to the existing technology.

- The atmospheric modeling component for CORAL was presented by Prof. Chandrasekhar, Dept. of Physics & Meteorology, IIT-Kgp. Numerical simulation studies on tropical cyclones using MM5 and RAMS model was highlighted. The existing study domain comprised of two spatial resolutions viz; 90 Km and 30 Km grid spacing. The MM5 model is run at IIT-Kgp on serial mode which takes approx. a day to compute for a forecast of 4 days with the 90 Km grid spacing. It was recommended to scale down the grid size to 10 Km such that features like radius of maximum winds could be captured in the event of a cyclone in the Bay of Bengal. It was highly recommended to compile and run the MM5 in parallel mode using MPI routines which is expected to save lots of computational time. IBM will help in

bench-marking the strategy of sharing computational resources, and in this context a plan needs to be formulated. Dr. Ramesh Natarajan (IBM) mentioned about remote visualization technology (deep thunder) using RAMS in parallel mode, pattern recognization etc. The importance of such technology in the present context to CORAL needs to be charted out and fully exploited.

- Dr. Ramesh Natarajan (IBM) suggested that one could look into the CORAL problems from a modeling-data-instrumentation-harzards-solutions perspective. This idea is best synthesized in the following matrix.

| Field → Topics ▼ | Oceans | Rivers | Atmosphere | Land |
|---|---|---|---|---|
| Modeling | Tsunami, Storm Surges, Coastal Erosion, Coastal Floods, HAB, Ecosystem, Ocean productivity, fisheries | River meandering, Riverbank flooding, Riverbed changes, tidal influences, estuarine ecosystem | Cyclones, Thunderstorms, Monsoon, Weather forecasting, Drought | Earthquake, Landslide, Deforestation, Drought, Microzonation, Coastal inundation maps |
| Data | | | | |
| Instrumentation | | | | |
| Hazards | | | | |
| Mitigation strategies | | | | |
| Societal Impact | | | | |

- IBM also mentioned in helping to get computational resources on remote basis to undertake computationally intensive tasks. This will enable interested post-docs and research scientists to work at IRL and IBM, New York to benchmark their source codes.
- Prof. Dube, mentioned about the starting of a Center in Thunderstorm research at IIT-Kgp for which DST, Government of India is willing to support. It was decided such a center will function under the umbrella of CORAL.
- Regarding disaster mitigation, it was decided involvement of NGO's will develop the sense of awareness at all levels. A program needs to be chalked out for discussions with the NGO community and how the task can be implemented.
- It was decided to conduct a socio-economic study for the past three natural disasters in India (Bhuj earthquake, recent Indian Ocean tsunami and Orissa super cyclone). Such a study has not been conducted earlier, and by doing so, strategy can be framed in event of futuristic events.
- Related to study on climate changes, it was decided to perform simulation of climatic impacts based on the data from IPCC.

## Part 2: Minutes of the second day (19 July, 2005)

During the second day meeting on 19 July, 2005 there were detailed discussions on the sub-topics covering areas on River Sciences, presentations made by participants, press meeting, starting of new courses for CORAL, possible funding sources, appointment of new Head to lead the CORAL and followed by the wrap up discussions.

- Dr. D. Sen from the Department of Civil Engineering, IIT Kharagpur had given a brief presentation of his research activities on river sciences, and his interest in numerical modeling of riverine systems in West Bengal. Some of the members expressed their opinion to use MIKE 11 for modeling the flooding problems associated with the river systems. After a brief discussion on this topic, technical details on how to address this problem were identified. Dr. Sen from Civil Engg Dept., IIT-Kgp developed his own code to model flooding issues of rivers. Dr. Tad Murty expressed his views on how to address the embankment, what are its merits and demerits. Dr. Murty said a similar problem was taken by Baird & Associates based at Canada, for a river in Malaysia. Dr. Murty's viewpoint is to model the pressure-heads at different locations in the river-flow and such a study will make an understanding on how the river digs along its natural course. He felt that, an embankment is a temporary solution to the problem, and not a permanent remedy.

- Dr. Hari Warrior from Dept. of Ocean Engg. & Naval Architecture, IIT-Kgp made a brief presentation on his research activities. He stressed the importance of an optical model, which he developed and can be used to address small-scale turbulence in the oceans. He mentioned about this work, which was recently accepted in the Geophysical Research Letters. He expressed his interest to use the General Ocean Turbulence Model (GOTM) for a detailed study on the Indian Ocean region.

- Dr. Sengupta from IISC, Bangalore had made a presentation of his research activities. Some of the interesting results on how the fresh water discharge from the rivers in the Eastern belt of India changes the density stratification of the regional seas were also discussed. Dr. Sengupta expressed his interest to work closely with Dr. Hari Warrior on this research problem.

- There was a press-meeting in the forenoon of 19$^{th}$ with Prof. S.K. Dube, Dr. Avijit Gangopadhyay and Dr. Tad Murty on establishment, plans and priorities of CORAL.

- It was discussed CORAL will be starting up new courses leading to M.Tech and Ph.D., programmes. Director, IIT-Kgp mentioned the course offering will be made later this year. Also it was mentioned, awareness of CORAL and its promising research on earth-science disciplines will be conveyed to the under-graduate students (from second year B.Tech students). This will attract the best talents to work on cutting edge technologies at CORAL and contribute to its developments.

- Dr. Avijit Gangopadhyay had briefed on the various possible sources of funding for CORAL. He also mentioned Univ. of Massachussetts will support short-term funding for visiting researchers from IIT Kharagpur for interaction with scientists/faculties at Dartmouth, USA. Submission of project proposals to various national funding agencies was also identified.

- Director, IIT-Kgp appointed Prof. S.Tripathy from Dept. of Geology & Geophysics as the Head of CORAL.

# Appendix IV

## Possible Funding Sources

1. Tsunami Project research grant from PBS&J ($20K)
2. Tsunami proposal to UN ($20K)
3. UMass Dartmouth (Travel and Faculty support funds) ($20K/year)
4. Director's Fund for Infrastructure (Building) – Rs. 7 crores
5. SUR grant from IBM ($100K) – Visualization and Computers
6. Microzonation of coastal West Bengal
7. River Flood Modeling and Monitoring – Rs. 70 lakhs
8. CORAL-UMassD-Harvard (modeling project) - $1million (3-5 years) (NSF-DST)
9. Tsunami Modeling Project (?)
   TTT will be prepared approx. for 250 locations in the Indian Ocean rim and which will be documented in final form as report by mid-September
10. Travel and Workshop support Fund from Indo-US Forum
11. GEMS
12. PAN (Pacific-Asia Network) – poc: Dr.A.P.Mitra
13. Ministry of home affairs
14. Shastri foundation –
15. Univ of Waterloo – math students – system integration—interdisciplinary problems – disaster management using probabilistic ideas
16. Coastal zone management for Orissa – Orissa Govt fund. – sign MOU
17. Cyclone Hazard assessment for West Bengal – Rs 40 lakhs (consultancy)
18. Faculty Recruitment – 5 faculty
19. CORAL seed fund – Rs. 5 lakhs.
20. Tsunami Atlas publication funds – Rs. 3 lakhs.

**Appendix V**
**Newspaper Clippings**

**The Times of India – June 25, 2005**

:TOI Kolkata;:Jun 25, 2005;:Pg 04 - City;:4

# IIT-Kgp to study and predict coastal disaster

**By Jhimli Mukherjee Pandey/TNN**

Kolkata: IIT Kharagpur has bagged the Union human resources development ministry offer to observe and predict disasters at coastal areas. The central offer has been a coveted and an important one following the tsunami disaster.

The institute's board of governors has recently given a go-ahead for the Centre for Oceans, River, Atmosphere and Land Sciences (CORAL), which will study coastal disasters, evolve a monitoring system to predict one and will also chart ways to manage disaster aftermath. The centre will also offer MTech and Phd degrees in oceans, river, atmosphere and land sciences.

The centre will work in collaboration with the University of Massachusetts, Dartmouth, USA, which has a similar centre that has been carrying out research along the Atlantic coast. CORAL will also involve the meteorological department in its observations as several oceanographic phenomena are related to atmospheric changes.

"We still do not have data to predict tsunami. Strong under-sea quakes trigger tsunami but we can foretell one from a continuous monitoring of minor quakes or other movement under the earth crust. CORAL will study these phenomena," the director of IIT Kharagpur, S K Dube, told ToI.

Though the institute has an ocean engineering and naval architecture department, CORAL will involve geology, geophysics and mechanical engineering departments.

"We have charted out an observational programme for collecting data and then plotting these to develop an advanced three-dimensional ocean circulation model for the Bay of Bengal and Arabian Sea. However, to ensure that our plan is in tune with the requirement of our coastal areas, we have invited experts from the US, Canada and across the country between July 18 and 21 for suggestions," Dube said.

CORAL will observe sea currents, temperature of the sea surface and map the depths, tides and the flooding pattern of riverine areas during high tides when sea water enters rivers. "The data collected will be computed into high resolution numerical models to improve our understanding of coastal ecosystem behaviour," explained Dube.

**From Indian Express, July 19, 2005.**

## Tsunami guru, IIT working on tidal atlas

*Murthy's work, which will comprise at least 250 charts, will benefit 40 countries, located in tsunami-prone zones*

**Nandini Guha**

**Kolkata, July 18:** A tsunami atlas is being put together by the Indian Institute of Technology, Kharagpore under the aegis of Professor Tad Murthy, the world's best-known tsunami scientist, who lives in the US.

Murthy, who is camping on the IIT-KGP campus for the next few days, is collaborating with IIT's CORAL (Centre for Ocean, River, Atmosphere and Land), to chalk out how much time the tidal waves will take to reach coastal locations in 40 countries across the globe.

"The headlines are over. Now if we know how much time we have in hand to remove people from vulnerable locations, then we can at least pre-empt disaster on that scale.

"It's basically a warning system", Murthy told Newsline from Kharagpore.

Murthy feels that his work is relevant because over three lakh people died in the 25th December disaster that shook all countries in the Indian Ocean rim.

"At least 15,000 people were killed in India's coastal regions alone.

"All these people could have been saved if there was either a warning sytem or if one could have anticipated how much time they had to flee from the waves", said Prof Murthy, who is now attached to the University of Ottawa in Canada.

Murthy's path-breaking work, which will comprise at least 250 charts, will benefit a minimum of 40 countries, which could be prey to the deadly waves in the future.

Murthy's team will also be working on some models, including the coastal inundation model.

"I will be traveling extensively within India, but I will keep coming back to the IIT to keep an eye on the project", said Prof Murthy.

Interestingly, the IIT KGP has already set up an observatory for carrying out diverse experiments in weather prediction.

**From The Telegraph, Kolkata, July 20, 2005**.

## Tsunami atlas

**Kharagpur, July 19:** The Indian Institute of Technology here today launched its Centre of Excellence for Oceans, Rivers, Atmosphere and Land (Coral) Sciences that is developing a tsunami warning system for coastal cities around the Indian Ocean, reports our correspondent.

“The development of a travel time atlas for the tsunami warning system is now in progress,” said S.K. Dubey, the IIT Kharagpur director.

Coral, he added, aims at bringing several new research areas related to natural hazards under one umbrella.

Over the past two days, scientists of the IIT and experts like Avijit Gangopadhyay of the University of Massachusetts, Ramesh Natarajan of IBM and tsunami expert from Canada Tad Murty were engaged in shaping up Coral.

Explaining the importance of the “travel time atlas”, Murty said in case of a tsunami, Coral would be able to issue warnings about when the waves will strike where. “During the tsunami in December, it took several hours to reach places like Chennai and Somalia. If we know where the tsunami was generated, we can refer to the travel time atlas and calculate the time it will take to strike other places in about 250 coastal areas across 40 countries around the Indian Ocean. On getting the warning, the local administration can plan its steps and evacuation.”

Dubey said a major focus of Coral’s activity will be mitigation of post-hazard effects

## From Business Standards, July 21, 2005

**IIT-KGP to set up CORAL**

Our Bureau / Kolkata July 20, 2005

Indian Institute of Technology-Kharagpur (IIT-KGP) has recently set up 'Center of Excellence for Oceans, Rivers, Atmosphere and Land (CORAL) Sciences to bring several research areas pertaining to natural hazards under a single roof.

The center would be working in collaboration with University of Massachusetts at Dartmouth, United States of America.

Development of a travel time atlas for 'tsunami warning system', mitigation of post-hazards effect would be some of the major activities of CORAL.

CORAL will also conduct a pilot project to study the impact of four major natural calamities that have taken place in the country.

"This analysis will allow CORAL scientists to develop a unified strategy for future hazard mitigation practices," said a release by IIT-KGP.

In association with tsunami experts from Canada, oceanographers from USA, computer experts from different parts of the world, CORAL would also try to develop a regional weather and ocean forecasting system.

West Bengal, Orissa, Andhra Pradesh (AP) and northeastern states would be of focus area of research for CORAL.

Rapid coastal erosion along Digha, Sankarpur and Sunderbans, designing and construction of coastal embankments, modeling and monitoring the river floods in north and central Bengal and thunderstorm research would constitute some of the major activities of the centre.

Some of this studies would be conducted in collaboration with Jadavpur University, Indian Space Research Organisation (ISRO) and foreign universities.

S K Dube, director, IIT-KGP, Avijit Gangopadhyay, University of Massachusetts, Tad Murty, tsunami expert from Canada, in association with several Indian scientists were busy in giving the final shape to CORAL over the last two day, said the release.

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## IIT-Kgp to prepare tsunami atlas

*By Jhimli Mukherjee Pandey/TNN*

Kolkata: December 26, 2004 was not the first time the world experienced a tsunami. Nor is there any guarantee that the killer waves won't strike again. Tsunami is a known phenomenon and it was not impossible to avert so many deaths last year had people been more aware of it, feels experts at the Indian Institute of Technology, Kharagpur.

The institute, under the aegis of the Union HRD ministry, has tied up with the University of Massachussets, Dartmouth, to set up a Centre for Oceans, Rivers, Atmosphere and Land (CORAL) that will eventually build a tsunami warning system for the Indian Ocean.

Avijit Gangopadhyay, an oceanographer from the university, will be guiding the CORAL. Incidentally, Gangopadhyay belongs to the 1979 batch of the institute.

"What is first needed is a travel time atlas. This will help one to know how long it will take for the earthquake to travel from its epicentre in the ocean to a particular coastal location. The shock waves will not reach Port Blair and Chennai at the same time for example.

"We will also try to predict the height of the waves in different coastal locations. Once these are known, post-disaster operations can be planned and many more lives can be saved," Gangopadhyay told ToI from Kharagpur.

The atlas will map the impact of tsunami waves in 250 stations and at least 40 countries surrounding the Indian Ocean will benefit from it, said Gangopadhyay.

"Such studies have already been done for the Pacific in more than a 1,000 stations and hence countries surrounding it are prepared to handle tsunami much better," he said.

But it is not tsunami alone that CORAL will study. The projects that have been designed will study other disasters like the Gujarat earthquake, Orissa cyclone and floods.

"Our aim is to try to mitigate the effects of earthquakes, floods and storm surges and plan evacuation strategies. A large part of our study will focus on West Bengal and the east coast because a large number of cyclones develop over the Bay of Bengal. We will develop high-resolution 3D models which will be used to forecast these disasters," Gangopadhyay explained.

CORAL will start functioning from August informed the institute's director, S K Dubey.