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# **Technical Session IVb**

## **Reaching the unreached**

**Nuclear Sciences, Space, Engineering,  
Physical and Earth Science**

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## SOME ASPECTS OF THE CONTRIBUTIONS FROM INDIAN WOMEN TO AEROSPACE

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As is well known, Aerospace is a multidisciplinary field integrating areas such as materials science, structures, electronics, aerodynamics, propulsion, software development etc. In India, several organizations and laboratories are engaged in high quality research and developmental activities in the field of aerospace. Indeed the activities include contributions from both men and women. In this write-up, a brief outline of some aspects of the contributions from women scientists, technologists and other professionals to this highly specialized field is given. Undoubtedly, the ensuing account is not exhaustive.

It must be mentioned that the information provided here is based on the lectures on varied topics, delivered in the seminar entitled 'Women in Aerospace in India' held at the National Aerospace Laboratories (NAL), Bangalore during December 2001, under the auspices of the 'Women's Empowerment Year - 2001' declared by the Government of India. To get an insight into the contributions from Indian women to aerospace, some of the topics covered in the seminar along with the name of the relevant organizations are listed below. It must be pointed out that in many of the investigations women have the lead roles.

Every woman in the field of aerospace has been referred to as an 'Aerowoman'. The Aerowoman of India proudly participates in the following activities:

- Activities connected with SARAS - the 14 seater multi role aircraft (NAL).
- Preparation of different types of polymers - fibres, resins, prepregs, composites - for aerospace applications (NAL).
- Development of surface modification technologies for aerospace - Development of sunshield mirror, silver plating of Mix-DEMux filters, gold plating on difficult to plate materials such as Al, Mg and stainless steel for space programs, development of ion plating of Al, Radar reflecting coating (ADA), high speed cadmium plating (HAL), ion nitriding of slat tracks (ADA), chemical milling of aerospace components (HAL) etc. (NAL)
- Development of pressure sensitive paints for wind tunnel studies (NAL).
- Science of flight simulation and its role in contemporary aircraft design in India (NAL).
- Design, fabrication and type certification of a fatigue meter for a fighter aircraft. A fatigue meter enables 'in service load monitoring' (NAL).
- X-ray and related studies on the effect of environmental exposures on polymers used in aerospace. Identification of structure - property correlation (NAL).
- Generation of moisture absorption at coupon level for the polymeric components used in HANSA - A two seater all composite aircraft developed at NAL (NAL).
- Qualification of materials used in HANSA for fire protection (NAL).

- Instrumentation aspects of steady and unsteady measurements in wind tunnels(NAL).
- Vibration studies on aerospace structures and systems(NAL).
- Impact of acoustic loads on aircraft structures(NAL).
- Air ships(NAL).
- Instrumentation for measuring visibility in airports(NAL).
- Cockpit ergonomics(NAL).
- Parallel processing(NAL).
- Modeling and system identification for aircraft stability and control(NAL).
- CFD tools and computational software for aerospace. Includes prestigious projects like SARAS, HANSA, LCA, ASLV/GSLV(NAL).
- NISHANT an unmanned aerial vehicle (DRDO,ADE).
- Development of DAIR(Dynamic Avionics Integration Rig) for LCA(ADE).
- High temperature carbon - carbon composites(DRDL,Hyd).
- International special operations - Tackling crowding of airspace without compromising on air safety(Air India, Mumbai) .
- Satellite mobile communication in the absence of land based cellular service(ISRO -ISAC).
- Mission computer software development for LCA avionics and weapons system(ADA).
- Design and development of satellite construction(ISRO -ISAC).
- Checkout operations for flight worthy satellites(ISRO -ISAC).
- Space astronomy- Astrosat, an Indian multiwavelength astronomy satellite(ISAC).
- System engineering in IRS(ISRO -ISAC).
- Lithium ion battery(ISRO -ISAC).
- Space environment and materials(ISRO -ISAC).
- INSAT 2E, Communication transponder switching(ISRO -ISAC).
- GSAT, Power management (ISRO -ISAC).
- Space craft maintenance(ISRO -ISAC).
- Payload data handling (ISRO -ISAC).
- Propellants(,LPSC,Valiamala).
- Quality assurance of software (VSSC,TVM, RelQ software).
- Sounding rockets(VSSC,TVM).
- Micro air vehicle(IISc).
- Flying experience on HANSA3(Banasthali Vidyapith).
- Cooling design of vanes,1700K,30bar(GTIRE).
- Aeroengine(GTIRE).

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- Secondary instabilities in shear flow(IISc,JNC).
  - Digital engine controller units(DECU) (AKAerotek).

**And many more items not listed here.**

It may be noted that the role of women in aerospace is not confined to any one area. Widely varying disciplines are being deftly handled.

Further detailed description of few specific items from the above mentioned list will be presented during the conference `Women scientists and technologists for national development '.

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## SCIENCE EDUCATION: REACHING THE UNREACHED

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EQUITY and excellence in science and mathematics education, spanning primary to higher secondary education, is the basic philosophy of the Homi Bhabha Centre for Science Education (HBCSE), an autonomous unit of the Tata Institute of Fundamental Research, based in Mumbai. HBCSE is financially backed by the Department of Atomic Energy, which supports a variety of research activities in nuclear and allied sciences, and in science education. Diverse programmes are underway at HBCSE: research and surveys in science and mathematics education, training programmes for teachers and students at different levels, development of different subject laboratories, including an integrated laboratory using easily available materials for the middle school level, and conducting science olympiads (biology, chemistry and physics). HBCSE is also involved in science popularization: panel exhibitions on history of science, women in science and sustainable development for a better world, along with a set of popular science books have been widely appreciated. All its programmes are sensitive to gender issues and there are constant efforts to reach other disadvantaged sections.

Programmes designed for girl-students, or with components of gender issues, and which, in turn, have an impact on science education, are highlighted here.

### RESEARCH PROGRAMMES

All research programmes of HBCSE are fed by contemporary scholarship in cognitive, social, historical and philosophical aspects of science education.

1. ***Gender and Science*** : Several research programmes have been undertaken in this area to unravel the manner in which girl students think about different issues, including science, scientists and mathematics. This understanding further informs the HBCSE experts in cognitive science and other areas, who are involved in the development of curriculum and other educational materials.
- a. ***Gender stereotyping of professions by students*** : This work established that students and teachers in rural and urban areas stereotype professions according to sex; aptitudes and preferences for a profession were ignored by both teachers and students. The research work revealed that girls were felt to be solely suited to take up typical low-paying professions, such as, teaching and nursing, or work as a domestic servant. The difficult or challenging professions, such as being a pilot, farmer or businessperson, were assumed to be meant for male students.
- b. ***Students' ideas about science and scientists (SAS)*** : This was an international collaborative project aimed at finding out how students in different countries think about science and scientists. Results revealed that Indian students, in sharp contrast to their foreign counterparts, had positive perceptions of science and scientists. In a drawing exercise, largely males were depicted as scientists.

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Another aspect of the SAS study involved finding out gender differences, if any, in the preferences of school activities among students, especially during off-school hours. While the female students reported only five activities connected to home chores (like making bread, butter or yogurt, sewing, weaving and knitting), the male students had a long list of 40 activities ranging from making different articles with tools to observation of the sky and environment. This study has important implications for school education and gender equity, especially for first generation female students.

- 2 The Health Education Programme attempted to find out students' understanding about different aspects of health and their understanding about communicable diseases. Students representing three different demographic groups - urban English medium, urban Marathi medium and a rural Marathi school frequented by tribal students - were chosen for this study. In the first part of this study, female students performed better than their male counterparts on all eight given categories of health, and the differences were statistically significant for four of the eight categories: i.e., physical, social, psychological and genetic. This gender difference in students' understanding about health needs to be capitalized upon by health planners and educationists.
- 3 Diagnosing Learning in Primary Science (DLIPS) attempted to diagnose alternative conceptions held by tribal and urban students in selected topics in primary science. Among several findings, there were marked gender differences in the responses of students. Girls and boys, both in rural and urban areas, came up with different types of lists when quizzed about non living or living items. The lists indicated that there were differences in the manner in which information was organized/ perceived by students. Again, this has implication for textbook writers, who need to take cognizance of the views/ideas of girl students too, while writing texts or drawing illustrations.
- 4 Development of Curricula and Educational Materials: The research work at HBCSE has fed into the print materials of the Center.
  - a The curriculum books titled, Homi Bhabha Curriculum, are sensitive to gender issues, which are appropriately addressed in the stories, text and illustrations.
  - b Foundation curriculum: An activity-based Foundation Curriculum (FC) in science, technology and society for secondary and higher levels is aimed at preparing students for coping with the complex demands of modern technological society. FC includes a set of eight books on different themes: Gender issues, including women in development and education, are included in the books on Education and Conflicts.
- 5 Science Olympiads: HBCSE is the nodal agency for conducting science olympiads in biology, chemistry and physics. In the final examination, Indian students participate in the International Olympiads, where they are known to perform creditably. Unfortunately, the representation of girl students has been unsatisfactory. HBCSE is concerned about this and would like to promote efforts to improve this situation.

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# RADIATION PROCESSING OF FOODS FROM LABORATORY TO MARKET

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Food is vital for our existence. Although we are self-sufficient in food production, with the growth in population the need for food security in terms of conservation and preservation is important and need of the hour. For economic stability of a nation, self-reliance, food security and controlled population are important prerequisites. Due to tropical climate, inadequate and improper storage facilities, seasonal nature of production, inadequate transport from farm to consumer result in 20-30% post-harvest loss in food. There are various methods to control the spoilage and infestation in food and extending the shelf-life. Radiation processing is one of the latest methods developed to conserve food. Radiation processing of foods can contribute to nations' food security by reducing post-harvest losses caused by insect infestation, microbial spoilage and physiological changes. More than 3 decades of research and development at Food Technology Division, Bhabha atomic Research Centre has demonstrated the usefulness of radiation processing of foods as one of the important and peaceful use of atomic energy.

Radiation processing of food involves the controlled application of energy from ionizing radiation such as gamma rays, electrons and X-rays for preservation of food. Gamma rays, commonly used for food are short wavelength radiations of the electromagnetic spectrum. Gamma rays are emitted by radioisotopes such as Co60 while electrons and X-rays are generated by machine using electricity.

Proven practical applications of radiation processing of food include.

- Destruction of pathogenic bacteria and parasites of public health significance in raw and minimally processed foods
- Microbial decontamination of spices and dry vegetable seasonings
- Insect disinfection of grains, legumes and other stored products
- Inhibition of sprouting in bulb, tuber and root crops
- Shelf-life extension of fruits and vegetables by delaying maturation, ripening and microbial spoilage
- Control of insect pests in fresh fruits and vegetables for quarantine purposes
- Enhancement of the refrigerated shelf-life of meat, poultry, seafood, fresh fruit and vegetables by reduction of spoilage causing microorganisms

The safety and nutritional adequacy of irradiated foods for human consumption is well established. About 43 countries including India have regulations permitting radiation processing of foods and 28 countries are commercially using this technology and marketing irradiated foods.

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To oversee all aspects of commercial food irradiation in the country the Government of India have constituted a National Monitoring Agency under the Chairmanship of Secretary, Ministry of Health and Family Welfare. The food items approved for radiation processing are notified in the Gazette of India as an amendment to the Prevention of Food Adulteration Act, 1954 and Rules 1955 permitted for domestic and export marketing and consumption are as follows : Rice, rawa, wheat flour, maida, pulses, raisins, dried figs, dates, onions, potatoes, garlic, ginger, spices, seafood (fresh and frozen) meat and meat products.

Despite the evidence of proven safety and usefulness of radiation processing technology, there is still reluctance within the food industry in many countries including India. This is due to perceived consumer resistance or an unwillingness either to upset the status quo or to be the first to promote a new technology.

Market experience in several countries show that consumers are willing to purchase irradiated food whenever it has been available, once they understand the benefit. Numerous consumer acceptance studies worldwide and our consumer survey indicate that majority of consumers are either ignorant or have preconceived wrong notions about the technology. Our experience has shown that giving correct information about the safety and benefit of the process, majority of consumers do accept this technology.

The journey from laboratory to market is not easy for any new food product or any new technology and more so for radiation processed food. The word 'radiation' creates flutters in consumer's mind even in highly educated class. It is wrongly associated with the horrifying memories of atomic bomb explosion of Hiroshima and Nagasaki or contamination of food due to Chernobyl accident. In radiation processing, food does not come in contact with radioactive material or cannot become radioactive because the energy level used are too low. Gamma rays emitted by radioactive material Co60 are used to preserve the food. The food is just passed through this path. It is just like sun rays being used for drying or X-rays used for screening the baggage at the airport. Radiation processing of food is safe. Its safety has been proven by animal feeding trials in many countries and thus accepted by International authorities like World Health Organization, International Atomic Energy Agency and Food & Agricultural Organization. Radiation processing does not have any adverse changes in food's nutritional as well as functional properties.

We are very proud that 'Annapurna Mahila Mandal' a Women's Welfare Organization working for last 26 years, for the up-liftment of downtrodden women has accepted the challenge in using radiation processing technology, first time in India for microbial decontamination of spices produced by them before putting it in the market. Thus from laboratory to market, radiation processing has just taken place. It was a small step in positive direction. Hoping the technology will reach more traders, entrepreneurs, farmers and will be utilized in the near future. We have tried various means to reach the technology to unreached under public awareness programmes. Some are mentioned below:

- Reaching the consumers through mass-media

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- Articles in Marathi and English local news papers and popular magazines
  - Press conferences
  - Radio-talks
  - TV talks
  - Information pamphlets in simple language in English, Hindi and Marathi
  - Teachers-Scientists meets
  - Lectures through various scientific organizations like

Indian Women Scientists Association

Association of Food Scientists & Technologists

Indian Dietetic Association

National Association for Applications of Radioisotopes and Radiation  
In Industry (NAARRI)

Indian Association of Nuclear Chemists and Allied Scientists (INCAS)

Nuclear Society of India (NSI)

Indian Society of Environmental Science & Technology (ISEST)

Marathi Vidnyan Parishad (MVP)

Maharashtra Academy of Science (MAS)

- Consumer sensitization/education programmes by serving preparations made from radiation processed foods and conducting surveys in canteens and seminars
- Exhibitions with non-irradiated and irradiated food products display
- Free samples of radiation processed spices in various forums.

We hope that women organizations take the lead in convincing the consumers about the importance and usefulness of this technology in delivering wholesome and hygienized food, thereby reaching the unreached.

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# REACHING THE UNREACHED: MORE DISSEMINATION OF EARTH SCIENCE

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## MEANS TO DISSEMINATE

Teaching of Earth Sciences is broadly confined to description of natural disasters in geography lessons at school level. General awareness of Earth System Science is very low. Some associate it with folk traditions and superstitions. Often any public discussion or description would lead to matters pertaining to astrology, superstitions regarding eclipses. The same would not be the case in a discussion on aeroplanes, textiles, medical science, investment, etc. Such subjects receive sufficient attention and evoke informed interest. One must concede that these issues have greater impact on daily urban life. However, if the level of consciousness about scientific issues is to be raised among members of the public - who absorb impacts of most scientific endeavours - the view of science as belonging to all, not only those who receive advanced training has to be propagated and sustained.

Beginning at the school level - where most people leave behind the book-learned concepts of science - it is seen that Earth Science contains descriptions of morphological forms - mountains, rivers, seas, desert. Following this is the chronicling of natural disasters. Few- I hope not many more- would have to compare the description of an earthquake with the real-life experience.

Few would ever visit a mountain region, the sea or glimpse a volcano.

The Science is made up of the inferences about processes - not from the description of a few events. It is this continuity - a concept of Earth as a system - as a continuous chain of processes - of which these events are only a manifestation. Such concepts are widely absorbed about society, mortality and wealth.

There are only two kinds of lessons that impart understanding - not information. One is:

Actual experience, explanation with models, time and effort required to impart understanding.

The other is: Understanding by analogy, quoting examples of processes and relating them to the everyday experiences of the target audience, ie. ; by impact of processes are understood by conducting a dialogue.

Syllabus at school level: contains many examples which impart information, dialogue about these events would impart understanding.

Events reported in national and international media capture wide attention. Bigger the disaster, greater the attention. In this process underlying questions are obscured. Myths and suppositions get wider coverage and memories of these speculative ideas remain. It is the preparation of background material that needs attention in clearing popular misconceptions and in explaining processes and the paradigms that form Earth System Science. What adults can read and assimilate from the media must find an echo in the lessons retained from the classroom.

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## WAYS TO EMPOWER

Earth Science is a rapidly developing field for example: Geographical Information Systems gaining use and being adapted to acquire and analyse different types of information. Exploration, exploitation and estimation of reserves of groundwater will rapidly become the domain of self-organised groups than with the traditional Government agencies. The same is true for pollution prevention, monitoring and elimination. In each such co-operative group endeavour it has been seen that women in the concerned group show more commitment and resolve in transforming issues. An example is the Chipko movement.

In this light, it is essential that understanding of Earth Science be propagated in definable terms to empower these groups with understanding of the causes and effects of the issues they face.

## INTERDISCIPLINARY UNDERSTANDING

Assimilating the impact of other sciences into the discipline in which one is working is another important aspect of 'reaching' others. In the networked, cause-effect related environment of today's technology, a modicum of inter-disciplinary awareness is an essential requisite.

Material for such understanding could be prepared in different format - more quantitative, drawing upon similarity of underlying mechanisms and mathematical relations existing in different disciplines. This informed and informative approach would be in tertiary format and need not address the concerns of public awareness.

More information about opportunities for study and employment in various disciplines of Earth Science need to be widely disseminated. The importance of early information reaching the youngest target population needs emphasis. The stereotype of male-dominated and female-dominated work preserves needs to be demolished as has gradually been accomplished for the disciplines of medicine, engineering, software and administration.

Relevance of Earth Science to other areas of science and technology, inter-relations of multi-disciplinary nature, characteristics of these relations and assessment of their probable effects are very important areas that need to be addressed in increasing awareness of Earth Science.

## EARTH SCIENTIST'S ROLE

The word 'Environment' is on everyone's lips today. The actual study of these effects is based on Earth System Science. As also the storage and exploitation of groundwater. These are everybody's concerns. Not just of the Earth Scientist. However, not everyone is well-informed about these issues. It is necessary in the coming years to broad-base the concerns of Earth Scientist. In efforts to disseminate the paradigms of our discipline, emphasize the inter-relatedness of the technological world with the natural world and conserve natural resources, the role of the Earth Scientist needs to be more pro-active than ever before.

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## TOWARDS WINDOWS THAT ARE ENERGY EFFICIENT

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Space conditioning of residential and commercial buildings accounts for substantial parts of the annual energy consumption in many countries. Generally this amounts to about 40 % and about one sixth of this is required to offset heat losses through windows i.e. roughly 7 % of the annual energy consumption is tied to fenestration performance. It is believed that similar numbers are valid for many countries. Hence it is obvious that window properties have a significant effect not only on visual and thermal comfort but also on energy consumption at a global level.

New windows are being installed annually in most of the countries, adding to that already exist and their number keeps going up every year all over the world. By blocking unwanted heat gains and reducing the need for air conditioning, a one meter square Electrochromic Window (ECW) in a commercial building can save about 70 kilowatt-hours of electricity per year. The building industry thus represents an enormous potential market for ECWs. In the transportation sector also ECWs can play a similar important role in addition to applications such as sunroofs. Electrochromic windows are tomorrow's option for energy efficient windows.

**Electrochromic windows**, a relatively new technology, are built from several layers of thin films deposited on a transparent base, such as glass. These thin film devices have a unique property that with a momentary flow of a small electric charge, they can change from being clear to heavily shaded. Depending on the amount of sunlight, the time of the day, the season, or the personal preferences of the user, the density of the colouration can be controlled. This kind of dynamic control of the incoming radiation offered by electrochromic windows make them **Smart Windows**.

Research in electrochromics at National Physical Laboratory has a long history. Our earlier efforts were directed specially towards possible application of electrochromic technology for display applications. Some of the inherent drawbacks like limited switching speed were mainly responsible for hampering further advancements and possible commercialization of these devices. Non-display applications based on electrochromic technology, not requiring fast switching like ECWs are more promising. Though challenging, these applications have raised the potential of the electrochromic technology to a very high level. Motivated with the ever-increasing demand of the energy saving pathways, we ventured into R & D activities related to the energy efficient or the so-called Smart Windows.

The most important issue for this kind of applications of the electrochromic technology is the requirement of various large area uniform coatings of desired thickness that constitute an ECW. With due consideration to the cost factor, which is of utmost importance for developing any technology for wide scale applications, we at NPL, could not continue with the conventional thin film technology but had to switch over to newer multidisciplinary techniques involving

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basic physics and chemistry, materials synthesis, process development and device packaging. The most important step in this direction was to adopt SOL-GEL based technique, well known for its many advantages allowing tailor making of a variety of thin films. Our parallel exploratory efforts have resulted in arriving at modest success for preparing the other components for fabricating ECWs .

We are still on our way to reach our ultimate goal of fabricating prototype large area Smart Windows. However our sustained efforts in this direction have led to development of components of ECWs with desired specifications and initial attempts of fabricating the ECWs have shown very encouraging results. In the process we have successfully filed international patent in addition to a large number of publications in reputed international journals, deliberations / programmes in many national, international conferences / symposia / training schools. Our extensive R & D work over the period will result in the award of Ph.D degree for some of the young students.

The skills developed over the years, the understanding of various phenomena involved and the encouraging results shown by our prototype small size ECWs have encouraged us for further extending our R & D efforts to power the ECWs with photovoltaic cells. The integration of ECWs with appropriately rated photovoltaic (PV) modules is not only technically viable due to compatibility of the electrical characteristics of the two devices, but such integration allows smart windows to be largely solar driven and also aesthetically appealing.

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# MATHEMATICAL MODELLING OF MARINE BIOGEOCHEMICAL CYCLES

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Modelling of biological processes in the euphotic zone in upper ocean is of interest because of the possible regulatory role of photosynthesis in ocean-atmosphere carbon flux, estimation of fisheries potential and influence on sea surface temperature. Energy flow between various components of the marine ecosystem is as follows: Phytoplankton grow using inorganic nutrients and solar radiation for photosynthesis (primary production), zooplankton graze on phytoplankton (secondary production), zooplankton are grazed by animals like fishes, birds, whales etc. (tertiary production). At C-MMACS, primary production in Arabian Sea is being studied in detail, since high spatial and temporal variability of various physical processes and abundance of nutrients is observed in Arabian Sea. The complexities involved in the modelling of marine ecosystem are the choice of state variables, the selection of significant biological, chemical and physical processes, the nature of the available data needed for simulation and data assimilation.

The contemporary models contain three to eleven state variables depending on the focus of study. The basic model consists of phytoplankton, zooplankton and nutrients as three variables and the processes like growth, mortality, grazing, excretion and the forcing functions like seasonal variation of mixed layer depth and solar radiation. All the processes influencing the ecosystem dynamics have various model formulations and contain a large number of model parameters. Since growth and grazing functions are intrinsically nonlinear, the nonlinear dynamics of the marine ecosystem is being studied in detail.

Phase plane analysis is carried out for the fundamental 3-component model of a marine ecosystem based on the uptake law of Michaelis-Menten and grazing laws of Ivlev and Mayzaud & Poulet. Partitioning the domain of permissible states of the system into regions of growth and decay of phytoplankton and grazing by zooplankton is shown to facilitate understanding of the large time behaviour of the system and construction of bifurcation diagrams. It has been reported in the literature that marine ecosystem models display limit cycles under certain conditions, especially when there is abundance of nutrients. These types of oscillations obtained from model simulations are often believed to be unrealistic and are sometimes encountered in tropical regions. Detailed study was carried out with the help of the phase-plane analysis of a class of basic marine ecosystem models to examine whether the nonlinear terms arising from mortality or self-grazing of zooplankton have significant effect in altering the linear stability conditions and thereby suppress the limit cycles or autooscillations.

Seasonal variation of chlorophyll can be predicted by a dynamical system model of the marine ecosystem coupled with a physical oceanographic model. As a first step towards the development of such coupled basin-scale models of ocean circulation and biogeochemical cycles, a class of dynamical models of marine ecosystems were studied in the context of the Arabian Sea. There

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is however a major difficulty in the calibration of contemporary ecosystem models on account of sparse data and a large number of model parameters. A new approach of macrocalibration is carried out, in which values of six parameters are determined by examining in detail the seasonal variation of chlorophyll and primary productivity keeping in view the observations of two Indian JGOFS cruises. Detailed simulations are carried out for a station in central Arabian Sea using both non-switching and switching versions of zooplankton grazing function in a contemporary marine ecosystem model (FDM model) consisting of seven components. The simulation results show the effects of dependence of grazing preference on prey density, on the behaviour of the ecosystem. The results of the simulation also provide a partial basis for developing correlations of primary production with chlorophyll and sediment flux.

The development of reliable models of biogeochemical cycles depends critically on evolving a methodology for objective comparison of model simulations with observations. Such comparisons can be used for parameter estimation, validation, data assimilation and, more generally, as a guide for model refinement. It was felt that the first task of such models ought to be to capture essential features of seasonal variation of chlorophyll a. Ship data are too sparse to form a basis for comparison and hence, one has to resort to satellite data. Issues concerning the accuracy of the satellite data on chlorophyll a obtained from coastal zone colour scanner were examined in detail. A methodology was developed for an objective evaluation of the relative success of an ensemble of simulations in capturing seasonal variability of chlorophyll a. Simulations were based on a seven-component FDM model applied to North Arabian Sea. Simulation results show the grazing control that allows preference to shift to the most abundant food type appears to give more reliable simulations than the grazing control in which the preference is independent of abundance

In order to get more realistic simulations, some modifications were introduced in the phytoplankton growth term in the FDM model. These modifications included the diurnal variation of solar radiation and seasonal variation of daylength at different locations in Arabian Sea. At present, the studies are being carried out on the different formulations for the uptake by phytoplankton in a two-nutrient environment. In FDM model, the inhibition due to the presence of ammonium on the uptake of nitrate by phytoplankton is modelled as an exponential term. This formulation results in an exponential decrease in the inhibitory influence of ammonium on new production. Also, it is observed that when either one or both of the nutrients are increasing in concentration, the total primary production decreases. To overcome these problems, a general law was proposed for the uptake of nutrients by phytoplankton in the presence of two nutrients. According to this law, the inhibitory effect of second nutrient on the first is linear for small concentrations and it saturates for large concentrations. Recent observations on the uptake of nitrate in the presence of ammonium are in good agreement with the proposed law.

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## EARTH SCIENCE

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Remote Sensing approach for developmental planning studies in Earth science is undergoing major changes as far as contribution of women scientist is concerned. One of the most classical example is seen in National Geographic Channel where a women scientist is seen to collect fresh lava samples in the field. In India also, we have many women scientists who are doing well in the approaches of exploration, description, data gathering, data processing and interpretation of processes and events. One of the major constraint which women scientist in India faces is their accountability and responsibility to the family they belong. Thus, sometimes a women scientist hesitates to enter the challenging areas of Earth Science. Maximum challenging earth science application areas requires considerable amount of field work. Keeping in view the constraints of women scientist in the given societal framework one area of opportunity needs attention for women scientist and that is **Remote Sensing Application**. This area will definitely allow the natural expertise of the women scientist into limelight. Women has a inborn instinct for societal needs and Remote Sensing Application provides the best platform to create action plan databases for Community Resource Development planning. Also because of the multispectral and multirate availability of the satellite imagery in different resolutions this technology helps in studying natural hazards and other issues related to the preservation and conservation of geologically important areas.

Government of India has already emphasized that in earth science applications, the prime consideration should be the well being of the society and industrial growth. Remote sensing studies seems to provide the answer. Increased understanding of the earth processes as well as emerging newer concepts and methodologies require interactive multidisciplinary research programme. With the computational capability women scientist can revolutionise in the thrust areas of Earth Science like Remote Sensing Application. This is one area where much of the exercise can be done in the laboratory with limited ground checks.

In future time will come when the potential and promise of research in Earth science both in basic and applied areas will see women scientists who will be generating a more positive research environment according to their capability.