

Detailed Project Report

# Program on Global and Regional Climate Change

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## 1. Climate Change and its relevance to India

Climate change is being recognized as a major threat to present day society because of its adverse impacts on ecosystem, agricultural productivity, water resources, socio-economy and sustainability in a global as well as regional basis. The Intergovernmental Panel on Climate Change (IPCC) in its fourth assessment report (AR4) states with very high confidence (90% probability of being correct) that human activities, since industrialization have caused the planet to warm by about 1°C. With the doubling of carbon dioxide content in the atmosphere, this trend is projected to cause average global warming of around 3°C compared to the pre-industrial level.

Observational studies, based on over hundred years of data collected by the India Meteorological Department (IMD) over the Indian region, have shown warming of about 0.5°C per 100 years on an all India average basis. Spatially, this is manifested as regions of higher values, and even pockets of cooling, over different parts of India. Future projections of climate change using global and regional climate models, run by Indian Institute of Tropical Meteorology (IITM) with different IPCC emission scenarios, indicate temperature changes of about 3 – 5°C and increase of about 5-10% in summer monsoon rainfall<sup>1</sup>. It is also projected that number of rainy days may decrease by 20 to 30% which would mean that the intensity of rainfall is expected to increase. Extremes in temperature and rainfall also show increase in their frequency and intensity by the end of the year 2100. A more recent study<sup>2</sup> using daily rainfall data for over 50 years shows significant increasing trend in extreme rainfall events over central India. Crop models run with such scenarios also show fall in food production per acre in India by about 20%. Further, hydrological models show fall in India's water resources which when combined with the recession of Himalayan glacier would pose a serious threat to the food and water security of the rising population of India. There is also possibility of enhanced vulnerability to our densely populated coastline of about 7500 km, because of rise in sea-level and greater frequency in high intensity tropical cyclones striking the Indian coast.

**Climate change will, in all likelihood, predispose India to enhanced threats from natural hazards linked to the atmosphere and oceans, besides stressing the availability of water and health of our key natural and managed ecosystems. There is therefore an urgent need to undertake systematic research on changes that are happening, and likely to happen, over the Indian region along with their linkages to the global changes. Assessment of impacts of these changes on the diverse sectors of activity at a lowest possible spatial scale requires to be made to facilitate community level actions for our sustainable growth. Such assessments involve intricate trans-disciplinary science efforts with cascading levels of uncertainties that must be carefully understood and documented for effective adaptation strategies.**

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<sup>1</sup> NATCOM Report (to be referred)

<sup>2</sup> Goswami et al. (2007), Science

In the past, studies on the magnitude of climate change, its science impacts, mitigation and adaptation have been pursued under several scientific establishments in India. Some of the studies that were conducted under the Ministry of Environment and Forest sponsorship formed basis of India's First National Communication (NATCOM) on climate change and are progressing at present under the second NATCOM, to fulfill India's reporting requirements under the UNFCCC. **To build research strengths and maintain a sustained flow of quality science into our national climate change agenda and India's international response there is need to launch a strong, well-coordinated program to address Climate Change Science that is of relevance to the Indian region.**

## **2. Issues and Research Needs**

The IPCC recent reports have identified a number of knowledge gaps and research needs. Many of these needs are valid in the Indian context and require continued scientific, technical and operational efforts in order to provide with the information required for dealing with climate change issues. Some of these of most direct relevance to developing countries are listed below:

- Continued research on the attribution of observed impacts of climate change to natural and anthropogenic forcings; enhancement of networks of systematic observations of key elements of physical, biological, managed and human systems affected by climate change particularly in regions where such networks have been identified as insufficient;
- Carbon, Nitrogen and Sulfur are important elements whose biogeochemical cycling is important to issues of environmental and climate change. Understanding of the exchange on these elements on a sub-continental scale is crucial for us.
- Process oriented investigations into the role of clouds, water vapor, tropospheric ozone and aerosols have to be conducted, with special reference to the tropical region. Regional and sub-regional scale modeling, aimed at understanding climate variability and occurrence of extreme weather events have to be taken up.
- Tropical climate is characterized by its variability involving phenomena such as the El Nino & Asian summer monsoons. Current projections made by models show little change or small increase in strength of the El Nino events. According to model estimates the Asian summer monsoon is likely to be more intense and variable with increasing green house gases in the atmosphere. However, the level of confidence in the predictions made by climate models for the tropics and the monsoon region remains limited due to inadequacies in representation of tropical processes and in simulations of El Nino as well as the monsoon.

- Integrated analysis of climate change impacts and vulnerabilities, including impacts of extreme weather events and climate variability at regional and smaller geographical scale required to be taken up. These impact and vulnerability analyses need to include the assessment of the economic consequences of climate change.
- Adaptation strategies and their link to improved climate information.
- Research on issues relating to Article 2 of the Convention (UNFCCC) (Dangerous anthropogenic interference with the climate system), particularly the methodologies to estimate climate change impacts on planetary scale systems such as the Thermo Haline circulation (THC) or the Indian Summer Monsoon (ISM).
- Development of a comprehensive framework for assessing risk of climate change, accounting for the existing/future level of scientific uncertainty, and socio-economic and environmental risks in policy-making related to climate change.

### ***Sectoral Concerns***

India is characterized by physio-geographically diverse and ecologically rich natural and crop-related biodiversity, with a large population that is projected to increase further. The population is principally rural-based, although they also support some of the largest cities in the world. Climate change will add to other stresses such as rapid urbanization, industrialization, and economic development, which contribute to unsustainable exploitation of natural resources, increased pollution, land degradation, and other environmental problems.

***Ecosystems:*** Substantial elevational shifts of ecosystems in the mountains and uplands are projected. At high elevation, weedy species can be expected to displace tree species—though the rates of vegetation change could be slow compared to the rate of climate change and constrained by increased erosion in the Greater Himalayas. Changes in the distribution and health of rainforest and drier monsoon forest will be complex. Sea-level rise and increases in sea-surface temperature are the most probable major climate change-related stresses on coastal ecosystems. Coral reefs may be able to keep up with the rate of sea-level rise but suffer bleaching from higher temperatures and increased acidity of ocean water. Landward migration of mangroves and tidal wetlands is expected to be constrained by human infrastructure and human activities.

***Hydrology and Water Resources:*** Increased temperatures and increased seasonal variability in precipitation are expected to result in increased recession of glaciers and increasing danger from glacial lake outburst floods. A reduction in average flow of snow-fed rivers, coupled with an increase in peak flows and sediment yield, would have major impacts on hydropower generation, urban water supply, and agriculture. Increased population and increasing demand in the agricultural, industrial, and hydropower sectors will put additional stress on water resources. Pressure on the drier river basins and those subject to low seasonal flows will be most acute.

**Food and Fiber Production:** The sensitivity of major cereal and tree crops to changes in temperature, moisture, and CO<sub>2</sub> concentration of the magnitudes projected for the region has been demonstrated in many studies. Although climate change impacts could result in significant changes in crop yields, production, storage, and distribution, the net effect of the changes region wide is uncertain because of varietal differences; local differences in growing season, crop management, etc.; the lack of inclusion of possible diseases, pests, and microorganisms in crop model simulations; and the vulnerability of agricultural areas to episodic environmental hazards, including floods, droughts, and cyclones. Low-income rural populations that depend on traditional agricultural systems or on marginal lands are particularly vulnerable.

**Coastal Systems:** Coastal lands are particularly vulnerable; sea-level rise is the most obvious climate-related impact. Densely settled and intensively used low-lying coastal plains, islands, and deltas are especially vulnerable to coastal erosion and land loss, inundation and sea flooding, upstream movement of the saline/freshwater front, and seawater intrusion into freshwater lenses. Socioeconomic impacts could be felt in major cities and ports, tourist resorts, fishing, coastal agriculture, and infrastructure development. International studies have projected the displacement of several millions of people from the region's coastal zone, assuming a 1-m rise in sea level. The costs of response measures to reduce the impact of sea-level rise in the region could be immense.

**Human Health:** The incidence and extent of some vector-borne diseases are expected to increase with global warming. Malaria, Schistosomiasis, and Dengue—which are significant causes of mortality and morbidity in many developing countries are very sensitive to climate and are likely to spread into new regions on the margins of presently endemic areas as a consequence of climate change. Waterborne and water-related infectious diseases, which already account for the majority of epidemic emergencies, are also expected to increase when higher temperatures and higher humidity are superimposed on existing conditions and projected increases in population, urbanization, declining water quality, and other trends.

### **3. Challenges and Barriers**

#### **a. Challenging Science Aspects for the Indian region**

We have seen an apparent increase in certain extreme events in recent years: the 2005-07 surge of floods events across many states and 2003 summer heat waves in Andhra; a large number of typhoons crossing - to cite but a few examples. Therefore, one of the current research needs is to respond to issues related to such extreme events, and to question whether climate change is related to increases in the frequency and intensity of extreme events. This includes the issue of whether global warming is already affecting us through amplified variability of the climate system.

The nature of the scientific evidence marshalled in climate change models is different from that common in empirical economic models, with their focus on parameter estimation and curve fitting. By contrast, the science models (covering a broad range of phenomena, not just temperature) are essentially based on the laws of physics and chemistry. While some of their parameters are uncertain, 'goodness of fit' is only one of the criteria used to select their values. Recent approaches have investigated physical uncertainties in the climate system by varying parameters within climate models and running ensembles of these models. More plausible outcomes (judged by their representation of current climate) are weighted more highly in the probability distributions produced.

We must assign high priority to the development of climate models for more reliable projection of climate change in the 21st century - with a special focus on the behavior (frequency and intensity) of extreme events (heat waves, cold spells, severe thunder storms, tropical cyclones, storm surges, severe storms, droughts, etc.) in the near future (circa 25 years hence). It is important that such modeling should be made in detail at a regional level so that projection outcomes can be adequately applied to impact or adaptation studies.

Another requirement that the models used to assess the change in the Asian monsoon under different climate change scenarios must be able to simulate the present day monsoon climate with high degree of fidelity. Almost all models, Atmospheric General Circulation Models (AGCMs) or Coupled Ocean Atmosphere Models (CGCMs), have large systematic bias in simulating the present day monsoon climate. Therefore, one important goal is to develop coupled ocean atmosphere general circulation model that would not only simulate the global climate well but also simulate the regional climate well.

To promote climate change research, it is also getting increasingly important to make better use of all available data from atmospheric, land surface and oceanic observations by suitably integrating and assimilating them. Further promotion of data integration and assimilation is needed at both national and international level to better utilize available data, in addition to the above efforts for better climate change research. To this end we must take up active roles in the Global Climate Observation System (GCOS) and the Global Earth Observation System of System of Systems (GEOSS). Standardizing data formats across disciplines and geo-referencing them for graphical manipulation will enhance utility in applications.

It is important to coordinate activities in climate change monitoring, advanced climate modeling, and impact and adaptation studies. In this regard, it is considered necessary to establish a database system where data obtained from systematic observation, data computed from climate change projection models, and outcomes from impact and adaptation studies are integrated so that information from different research areas can be made mutually sharable and more applicable to mitigation policies.

The focus during the next five years of science efforts to address the challenges of climate change should be the following:

- Improve understanding of the mechanisms and factors leading to changes in radiative forcing – aerosols, GHG Global Warming Potentials (GWP), cloud-aerosol interactions.
- Improving the quantification of the anthropogenic component of observed changes in climate and improving the estimates of natural influences and natural variability over the Indian region.
- Better assessments of the impacts climate change on Monsoons and El Nino.
- Understand and characterize the important unresolved processes and feedbacks, both physical (ice-albedo, water-vapour) and biogeochemical (Carbon, Nitrogen and Sulfur cycles), that critically influence the climate system. How emissions get transformed into the atmospheric concentrations?
- Reducing the uncertainty in the sensitivity of the climate system to greenhouse gases and other forcing through improved models and more reliable input datasets.
- Improve methods to quantify uncertainties of climate projections and scenarios, including long-term ensemble simulations using complex models. Provide probability estimates of projected changes along with quantified reliability levels.
- Improve the integrated hierarchy of global and regional climate models with a focus on the simulation of climate variability, regional climate changes and extreme events.
- Link more effectively models of the physical climate and the biogeochemical system, and in turn improve coupling with descriptions of human activities.
- Provide better impact assessments across sectors like water, agriculture, forestry and health over the Indian region.

## **b. Barriers**

The **number of climate change researchers and analysts in India is small** - the number of researchers involved on a continuing basis on all climate-change-related activities is less than a hundred. There is also a relatively clear institutional division between those working in the realm of the physical and those working in natural sciences.

**Not having an exclusive institutional structure to provide science-input places limits on the time that the top cadre of scientists can spend carrying out active research.** Within the climate science community, there is only some collaborative activity. These are mainly set up at **only individual/personal initiatives** and are therefore at a small scale involving a few researchers or groups. Collaborative activities among these groups are rarely catalyzed by institutional or programmatic structures. Therefore, **science efforts to understand and characterize regional climate changes or future projections over India are sporadic and fragmented, often supported by foreign agencies.**

**Also, lack of a dedicated coordination structure with access to sufficient funds, does not permit regular systematic investigations on a sustained manner. This also restricts interactions with international scientific community which is vital for exchange of ideas within and across disciplines or building of networks.** Researchers cannot afford to routinely go to national conferences, refresher training courses and other such meetings where they can meet and interact with international scientists and experts on a regular basis, which can lead to, sustained capability development.

**Interactions between the science and policy analysis community, are limited.** The linkages between climate analysts and the government in India are less institutionalized than in countries such as the US. Scientific bodies in India are not organized in actively providing policy advice to the government and links between scientists and policy makers often operate in an informal manner. Policy-making bodies solicit advice from scientists on a more immediate “need-to-know” basis. **In the realm of climate change, no comprehensive, interdisciplinary, authoritative document to inform the government has been produced.**

At present **there is no concerted program devoted to the science issues of climate change.** Under the NATCOM project institutions were brought together to produce assessments of climate change impacts on various sectors.

There is also an urgent need for building a critical mass of trained researchers who can take up science issues of climate change that are of particular relevance for India. Creating active foci of climate change research at the various leading institutes of the country will be an ideal method to build such research capabilities.

#### **4. Need for a Dedicated Program**

Dealing with complex science issues of climate change requires skills in a number of research areas such as climate, sustainable development, natural resource management and valuation, environmental impact analysis, environmental economics and institutional and societal adaptation. It is also important to combine such knowledge with the local and regional conditions to formulate effective response methods fine-tuned to specific situations. Enhancing science strengths at regional and local levels is therefore of immediate

importance for producing sound scientific assessments on which national response strategies could be based. This will also ensure India's effective contribution into international assessments and policymaking process. Without such initiatives the scientific understanding or implementation of global adaptation and mitigation strategies will not be sustained.

It is therefore necessary to create a **high-priority Mission mode Program to address the Science issues of Global and Regional Climate Change** at the Ministry of Earth Sciences. The program should establish strong linkages with leading international research groups and research centers involved in allied areas, and will be supported by a well equipped with state-of-the-art center of excellence for inter-disciplinary research & training in the are of science of climate change. The centre will also serve as a nucleus for research in the tropical and Asian monsoon region

### ***Objectives of the Program***

- ***To explore and assess targeted science-facets of climate change that are of high relevance over the Indian region, along with their global linkages.***
- ***Set up a dedicated research center with appropriate infrastructure to lead research initiatives.***
- ***Integrate existing research groups and develop new groups through the development of institutional research network.***
- ***Develop collaborative linkages with international institutions and research groups to enhance our research capabilities.***

### **Major Components**

**A. Program office on GRCC at the MoES:** Help articulate desirable R&D activities aimed at improving our understanding of regional climate change science and mitigating the adverse impact of Climate Change. Enable science inputs for devising/designing policy options, and identifying and persuading appropriate professional groups to implement these programs (e.g., quantification of radiative forcings by different climate implicated agents, especially aerosols, devising policy frameworks for guiding India's national policy and programs on global issues of the Environment and Climate Change). R&D aimed at advance identification of possible future adverse happenings.

Constitute a advisory Committee consisting of eminent scientists and professionals for the Climate Change Program. This will act as a guiding mechanism for the Ministry to identify specific thrust areas for research and important projects to be taken up and direct Program Office to implement them.

Establish a Centre for Climate Change Research to deal with all the science aspects of climate change to be collocated at IITM, Pune.

The Program Office will not only coordinate the establishment of the Centre for Climate Change Research at IITM, but also identify national research priorities on science aspects of climate change on an ongoing basis and proactively support and fund projects. It would also evolve a mechanism to network programs on climate change across national institutions.

Facilitate Inter-ministerial and inter-departmental coordination on S&T issues, Impact Assessment, Vulnerability & Adaptation, Mitigation and Policy development. Interact with other national agencies including NGOs and the private sector to encourage broader involvement of the community in the scientific issues of climate change.

To develop, sustain and progressively enhance the international interface particularly with developing countries.

## **B. Centre for Climate Change Research at the IITM, Pune:**

*The Centre will strive to harness the strengths in Science [with participation of national and international research groups] to better understand climate change over the tropics, in general and the Indian region, in particular to enable better assessments of impacts and vulnerability of different sectors for evolving effective policies for adaptation and mitigation anchored on value of sustainability.*

- *Enhance knowledge on regional climate change over the Indian region.*
- *Understand the nature of biogeochemical interactions and their response to environmental change.*
- *Study the impact of global warming on planetary scale phenomena like Monsoons and the El Nino over the tropical region.*
- *Create and update information-reservoirs relevant to the region to enable better assessments of changes and impacts based on current knowledge.*
- *Generate Technology based knowledge products based on climate studies.*
- *Identify and explore new areas of research that will contribute to the fundamental understanding of earth's climate system.*
- *Build linkages with national and international research groups to optimally leverage scientific capabilities for climate change research.*

These goals are envisaged to be achieved through:

- Creation of a multidisciplinary core competence in the area of climate change relevant to the region.
- Establishing a data infrastructure. Establish regional data bank and information network climate amongst national partners.
- Undertake collaborative research with national groups.

An indicative priority of science issues that the Centre can take up is given at Annex A.

It is proposed to establish this dedicated Center for undertaking research on Science aspects of Climate Change at IITM, Pune. While the existence of a critical mass of core scientists with experience in both theoretical and modeling aspects of climate science at IITM provides the basis, it would require major investment in physical and computational infrastructures as well as human resources for the success of such a Centre.

The centre will be hosted by IITM, Pune and will be headed by a senior scientist proposed to be designated as the Executive Director. During the initial phase, the Executive Director of the Centre will function under the direct guidance of the Director, IITM. This will ensure proper direction and mentoring of the centre in its formative phase. The center is proposed to be governed by a Council, and guided by a Science Advisory Committee.

#### Structure of the Proposed Centre

The centre will be hosted by IITM as a new program of IITM, Pune and will be headed by a senior scientist proposed to be designated as the Executive Director. While it will be under the general guidance of the Governing Council of the IITM, the Executive Director will have certain functional autonomy. During the initial phase, the Executive Director of the Centre will function under the guidance of the Director, IITM. This will ensure proper direction and mentoring of the centre in its formative phase. The various component Groups proposed are schematically illustrated in Annex B.

#### Components of the Centre for Climate Change Research

***Physical Processes Group:*** The main objectives of this group would be to undertake research work on the following aspects:

- Monitoring, source identification of various GHG.
- Aerosols; space time variability, chemical composition etc.
- Monitor and asses land use and land cover changes.
- Palaeoclimate reconstruction using various proxies.

The national coordination cell at the ministry would identify several thrust areas relevant to climate change issues of India and fund major field and observational programs to address these issues involving scientists of IITM as well as several other institutions/organizations in India. The Physical Process Group would utilize the outcomes of the observational programs and work towards improving various components of the global and regional models and ultimately the simulation of regional climate in this part of the world. This group also will undertake Palaeoclimate and Palaeo modeling studies to identify climate analogues in the past so that some estimate of future evolution of climate could be made.

***Core Modelling Group:***The simulation of Indian Monsoonal climate in global and regional models has been a great challenge for the climate modeling community world over. It is necessary to develop a coupled ocean-atmosphere modeling strategy for making long scenario runs. This would be achieved by first identifying one or two coupled models that are being used at other leading climate centers in the world and then by tuning the physical processes in the model to achieve realistic monsoon simulations. This involves a core team of experts on various components of global ocean and atmosphere model to be able to make necessary changes to the codes and to incorporate the inputs provided by the physical process group of the center. Some of the responsibilities of this group include:

- Development of coupled Ocean-Atmosphere Modeling Strategy.
- Generation of long scenario runs.
- Assessment of uncertainties in monsoon under climate change scenarios.
- Assessment of the role of aerosols on Indian Monsoon?
- To understand what will happen to monsoon hydrological cycle under different GHG scenarios.
- To develop a modeling set up to readily undertake various sensitivity studies to provide reliable answers to outstanding issues relevant to climate change.

***Climate Scenarios Development Group:*** The immediate and most important deliverable of the newly proposed center would be to generate an ensemble of high-resolution regional climate change scenarios to be utilized by several groups in the country that are involved with impact assessment and development of adaptation and mitigation policies and methodologies. This involves running several global and regional climate models with different GHG scenarios for more than a century. The group will not only run the models for generating a large ensemble of scenarios but also evaluate and develop suitable downscaling methodologies so that the group involved with outreach and data products can use these to develop tailor made climate change data products for their use by several groups in the country and the region.

**Impacts Assessment Group:** Though it may not be a prime focus of the center to carry out impact studies, an effort will however be made to develop a small group of experts to undertake studies to examine the impact of climate change on some important sectors such as the water resources with a special emphasis on the Himalayan river systems, agriculture, human health etc. These studies will either be done by the group itself or in joint collaboration with other groups in the country.

**Outreach and Data Products Group:** One of the main deliverables of the center is to generate reliable high resolution regional climate change scenarios for their use by several groups in the country and, if needed, in the region. This involves proper storage and retrieval of large data that will be generated by the models and to tailor them to suit the requirements of impact assessment groups. Also, it is equally important to interact with the society and reach the people to popularize the science of climate change and make the work done at the center relevant to the societal needs. These are some of the tasks that the Outreach and Data Products Group will undertake. The group will implement suitable graphical platforms to enable geo-referenced visualization of scenarios of change for greater utility. The group will also have people with expertise on data base management and data mining techniques.

**C. National CC research network:** Research thus far on science aspects of climate change in India have gone ahead in a more or less individual basis, based on interests and available opportunities. In view of the serious demands placed by the future threats of climate change consequences on India, it is now necessary to make targeted efforts to provide relevant inputs for policy decisions and developmental planning. When this requirement is viewed in the context of the highly multi-disciplinary nature of climate change science, then the need for networked research can be appreciated.

The research network will support a blend of basic science research, supporting research (on clearly identified problem and knowledge/information deficient areas of relevance to the Indian region), enhancing capacities through training workshops, research fellowships, interactions with visiting experts and dissemination of information.

To begin with the Climate Change Research network nodes (SCRG) will be set up for important aspects such as observations, process modeling and oceanic response to climate change at leading national institutions and university research centers.

**D. Foster International linkages to enhance institutional research strengths:** International collaborations that in the process of formalization like with the DEFRA and UKIERI, UK and the NOAA, NASA, USA will be used to train scientists for the new centre at IITM. These international programs will be also used build technical expertise of other potential network research centers to broaden the research base on science issues of climate change.

A large number of international institutions, such as MPI, Germany, MRI, Japan, ICTP, Italy, IIASA, Austria, are keen to establish joint research projects in the area of climate change science. Some of these could be identified based on common aspects of interest and developed into collaboration proposals or bilateral programs.

### Management of the Centre

The Centre will be managed through the Governing Council of IITM consisting of eminent scientists from within and outside the subject area. The council meets twice in a year and oversee the activities and progress of the centre.

The Research Advisory Committee (RAC) of IITM meets once a year and reviews and advices on the activities of the Centre.

The Centre will be advised and steered by a Science Advisory Committee (think tank) – to be set up by MoES.

### Requirement for a High Performance Computer System

Both the development of a coupled modeling strategy as well as to generate a large ensemble of future climate change scenarios using a suite of global and high resolution regional climate models involves a large number crunching capability. This is possible only when a dedicated super-computing or a very high performance computing facility is available with the center. This HPC should also be augmented with a large data storage and retrieval system.

### Human Resources

The centre is proposed to be established with a strength of about sixty scientists and twenty support staff, which shall include ten IT personnel and administrative staff.

The scientific strength will be built in a phased manner as detailed in Annex D. It is expected to recruit scientists coming out of the major capacity building program being launched by the ministry for making available trained manpower for different areas of atmospheric sciences.

The dedicated research center at IITM, Pune will be started with 10 core scientists from IITM to begin with and will recruit 50 scientists at different levels in the first 5 years. The center will be headed by a senior scientist to be designated as Executive Director/Chief and the rest of the scientists will be working in 5 thematic Groups concerning different aspects of the Science of Climate Change. In addition to the scientists, the center will need 20 support personnel to manage general administration, accounts and IT services to all the groups.

The IT services people will also manage the High Performance Computing facility to be established at the new center.

## 5. Strategies for Implementation of the Program

The four pronged strategy, as outlined in the previous section, is proposed to be adopted to achieve the objectives of the Program. Firstly, it is proposed to establish a program office that will function at the Ministry of Earth Sciences to coordinate and implement the whole initiative. Parallel efforts have to be taken up to establish a dedicated research centre at the Indian Institute of Tropical Meteorology, Pune. These two main actions shall constitute the first phase of action. Thereafter, a “think tank” mechanism in the form of a Steering Group for the Program will be constituted to formulate the thrust areas and targets for research.

In the second phase, it is proposed to create Specialized Climate Change Research Groups (SCRGs) at key national institutions to support the research efforts of the Center at Pune. Simultaneously, national research groups working at leading Institutes, laboratories, university departments and NGOs will be identified to take up targeted research in crucial science aspects of climate change that are of immediate relevance to India. These research Groups will form the nodes of the proposed national climate change science research network.

International collaborations – both existing and new, will be oriented and leveraged to build research capacities. This will be enabled through international meetings, exchange visits and targeted actions for acquiring research tools.

## 6. Program Management Structure

A Science Advisory Committee (SAC) to be constituted with a group of eminent scientists from the subject area will guide the program. It is proposed to have overlapping memberships with the management and advisory structure of the proposed centre at IITM to ensure complimentary research efforts. A senior scientist will be appointed to manage the Program, and also act as the Member Secretary for of SAC. Program components and management structure is given at Annex C.

## 7. Manpower

### Centre for Climate Change Research, at IITM, Pune

Scientist G	1
Scientist F	10
Scientist E	17
Scientist D	17
Scientist C	15
IT support	10
Administrative support	10

(Details provided at Annex D)

## 8. Budget

(Expenditure indicated in Indian Rupee Crores)

Items of Expenditure	2008-09	2009-10	2010-11	2011-12	Total
<b>Centre for Climate Change Research at Pune</b>					
<b>Infrastructure</b>					
New Facility to host the centre and accommodation for scientists: Lab and office space (Non recurring)	2.0	10.0	-	-	20.0
<b>Equipment</b>					
HPC (High Performance Computer system)	-	-	-	35.0 (FE)*	35.0 (FE 35.0)
Other Equipment [Monitoring, Front –end computers, peripheral storage, setting up laboratory, observational studies]	3.0	10.0 (FE 4.0)	4.0 (FE 2.0)	1.5	18.5 (FE 6.0)
<b>Man power</b>					
<b>Salaries</b>					
First 5 yrs 60 Scientists + 20 Support Staff	-	5.5	6.5	7.5	19.5
<b>Manpower Development</b>					
Training etc.	-	2.25	1.25	1.25	5.0
<b>Running Costs</b>					
<b>Facilities</b>					
Electricity, water, maintenance, security etc. and other contingencies	-	2.5	1.25	1.25	5.0
<b>Subtotal</b>	<b>5.0</b>	<b>30.5</b>	<b>22.5</b>	<b>46.5</b>	<b>104.5 (FE 41.0)</b>
<b>Program on Global and Regional Climate Change</b>					
Funds for extra-mural research projects **					
Observational/Monitoring	-	10.0	13.5	8.0	31.5
• Flux Network stations					
• Nitrogen cycle studies					
Process Studies to support modelling	-	3.25	2.0	3.0	8.25
• Aerosol Brown Cloud					
• Tropospheric Ozone etc.					
Trans-disciplinary climate change impact studies	-	1.25	1.0	1.0	3.25
• Climate change impacts on water availability and other sectors					
<b>Subtotal</b>	<b>-</b>	<b>14.5</b>	<b>16.5</b>	<b>12.0</b>	<b>43.0</b>
<b>Grand Total</b>	<b>5.0</b>	<b>45.0</b>	<b>39.0</b>	<b>58.5</b>	<b>147.5 (FE 41.0)</b>

## **9. Deliverables and Benefits**

- Well-researched, comprehensive and critical assessments of climate change issues of relevance to the Indian region.
- Advanced modeling capabilities for high quality regional scenarios of climate change and better knowledge of influence of climate change on monsoons which to provide science inputs for policy decisions and international negotiations.
- A Centre for Climate change research at Pune, with advanced research capacities to take up climate change science issues on an ongoing basis.
- a network of research groups with state-of-the-art scientific capabilities to deal with different issues of climate change of national and global relevance

## **10. Sustenance**

Science Inputs for Climate change issues is set to become an ongoing requirement and as such the creation of a dedicated program and center will cater to this national requirement. At the end of the project period it is proposed to undertake a comprehensive review and decide on future course of action, including regular funding.

## **Annex A**

### **Major Science Issues**

#### **Observed Aspects of climate change**

##### ***(a) Regional Detection and Attribution of Climate Change***

Because of the complexities of natural climate variability on regional to global scales, detection of anthropogenic climate changes (and their effects) and attribution of those changes to specific causes is a difficult “signal to noise” problem. However, the relatively rapid and coherent character of current anthropogenic climate change has allowed detection and attribution of anthropogenically induced changes in global air temperature patterns, subsurface ocean temperatures, tropopause heights, and other global-scale climate indicators in recent years. For scientific as well as practical reasons, **the current grand challenge is extension of detection-and-attribution fingerprinting methods to regional-scale changes and to a broader, multidisciplinary range of variables.** Targeted research studies are required to characterize regional-scale climate changes or change in impact-relevant variables, such as temperature, precipitation, river flows, etc, that can be separated from natural variability and confidently attributed to global anthropogenic causes.

##### ***(b) Climate Change in Sensitive Environments***

High elevation regions, coastal environments and conserved national parks are critical for a host of natural resources, including water supply and biologic diversity, as well as an important economic resource supporting recreation. These areas are assumed to be the most vulnerable to the impacts of global climate change. They are also among the least studied, monitored, or instrumented within impact assessment sciences. Observed changes of climate parameters and other related aspects need to be closely studied for critical assessments.

##### ***(c) Paleoclimatic studies***

As there is considerable uncertainty in predicting the future climate due to uncertainties in the emission scenarios as well as the model deficiencies, some analogous situations in the past climate may provide important insight to evolution of the present climate. Therefore a high resolution multi-reconstruction of regional climate and its interaction with environment can give us insight on influence of climate change on biological system and ecosystem and on hydrological processes.

## Climate System Process

**(a) Aerosols and regional climate:** Both natural aerosols (e.g. sea salt, dust etc.) and anthropogenic aerosols (e.g. black carbon, sulphate etc.) can influence the climate directly by modifying the surface radiative balance and indirectly through modification of clouds and their distribution. Large space time variations in their concentrations as well as \*\* composition make it difficult to assess their climatic influence. As a result, whether the aerosols augment or oppose the GHG warming remains unclear. Therefore there is a strong need to compile comprehensive observational data box of the space time variation of both natural and anthropogenic aerosols. There is a need for considerations of the different species, and their physical characteristics together with their spatial distribution. This will enable the quantification of aerosols by altitude, size and chemical composition leading to better assessment of possible regional impacts. Research efforts are also required for improvements of measurements of optical depths for furthering our understanding of the energy distribution in the atmosphere that critically influences cloud formation and rainfall rates.

**(b) Bio-geochemical cycles:** Bio-geochemical cycles, make earth the living planet. Rapid intervention of the physical environment by human activities are influencing these cycles in permanent ways which is a cause for concern for future growth and development. The Indian region is covered by a range of ecosystems from tropical forests in the extreme south to boreal forests in the north and from temperate forests in eastern Asia to deserts in western Asia and tundra in the Himalayan Mountains. These ecosystems account for about 20% of the potential global terrestrial net primary productivity and for a similar fraction of the carbon stored in land ecosystems. Clearly, the Indian sub-continent is of critical importance to the understanding of how changing climate and human impacts interact to influence the structure and functioning of ecosystems and the biosphere. There is therefore an urgent requirement to monitor – on a long-term basis, the fluxes of important trace gases over varied environs of the Indian region. Studies to monitor and model Carbon, Nitrogen and Sulphur need to be undertaken.

## Modelling

Simulation of Indian monsoon has been a great challenge for the global modeling community world over. Though considerable progress has been made in simulating the mean climatological features of monsoonal climate, the rainfall simulation on different spatial and temporal scales still remains a problem in most models. Any improvements that can be brought forward in the models to better the monsoon simulation skills involves a thorough and detail re-look at various physical processes such as convection, radiation, land surface processes etc and their parameterization in the climate models. Most of the parameterizations used in the global models are based on extensive field observational studies carried out else where and may or may not represent the regional peculiarities in

this part of the world. Hence, the improvements in modeling Indian monsoon can be achieved only by a two pronged strategy wherein carefully planned extensive field experiments to verify some of the coefficients that are being used in various physical parameterizations in the models and to make GCM sensitivity studies to incorporate the new observations and test these. Recent research has also brought out that Asian monsoon is a result of coupled ocean-atmosphere interaction. As a result coupled ocean-atmosphere models are required for estimating influence of climate change on the Indian monsoon. This is a huge task and needs a large pool of experts on various components of atmosphere and ocean modeling. The major science questions that can be addressed by the modeling efforts could be:

**(a) *Producing reliable monsoon simulations under different scenarios***

What will happen to monsoon hydrological cycle under GHG scenarios?

As the country's economy still depends significantly on agriculture and since agriculture in the country is largely rainfed, there is a strong correlation between monsoon rainfall and agricultural production. Hence, for policy planning, it becomes imperative to have a reliable estimate of what may happen to the monsoon hydrological cycle under different GHG scenarios. Unfortunately, such a reliable estimate is not available today due to various reason such as model biases, uncertainty in the GHG emission, availability of computing resources etc.

One of the priority objectives of our project will be to generate such reliable estimates. It will involve development of a global coupled ocean-atmosphere model with reasonable monsoon climatology to be down scaled by a suite of high resolution regional models.

**(b) *Statistical downscaling***

Because of parameterization, existing GCM/RCM processes cannot be simply scaled to finer resolutions. Furthermore, at resolutions around 10 km, current physical parameterizations may not be adequate and problems will arise as the separation between what should be explicitly resolved and parameterized becomes ill defined.

**(c) *Quantifying Model Uncertainties***

Improve methods to quantify uncertainties of climate projections and scenarios, including long term ensemble simulations using complex models; Improve the integrated hierarchy of global and regional climate models with a focus on the simulation of climate variability, regional climate changes and extreme Events; Link more effectively models of the physical climate and the biogeochemical system, and in turn improve coupling with descriptions of human activities.

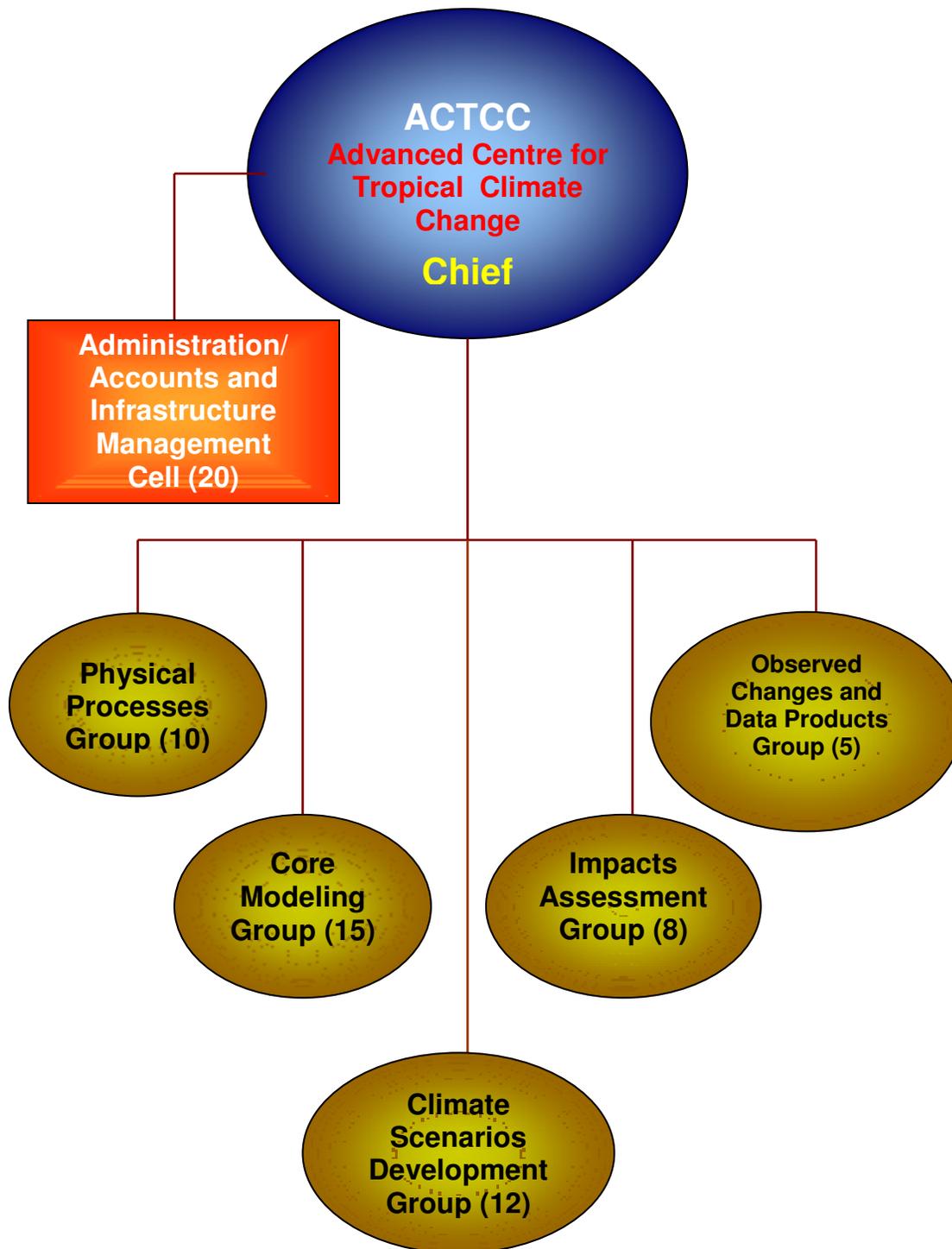
**(d) Role of aerosols on regional climate:**

Atmospheric brown haze or atmospheric brown cloud (ABC) of anthropogenic origin over India and China have raised considerable concern on its possible impact on regional climate. At present, it is unclear whether it would add to the influence of GHG to Indian monsoon or oppose it. Current estimate of their influence on the Indian monsoon from various studies are contradictory. A comprehensive modeling study with better input from better observations (as described earlier) using more realistic model is required to make a reliable estimate of the influence of ABC on monsoon hydrological cycle and extreme events. This is another major objective of the Centre.

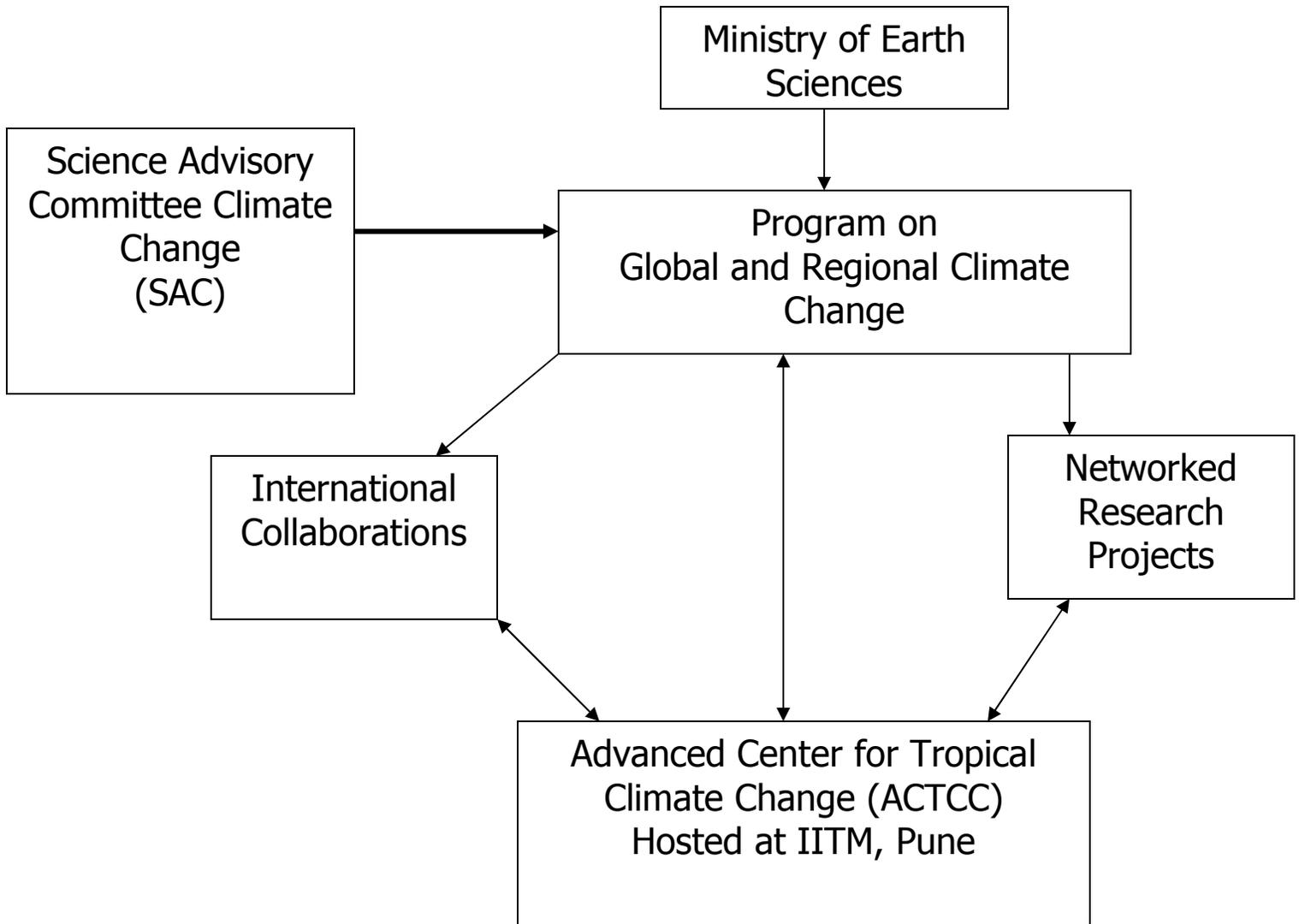
**Impacts and Vulnerability Assessments for sectors:**

- (a) Develop techniques to translate climate information (both climatological and model prediction) to useful applications by different stake holders, (e.g. research groups engaged in impact and V&A assessment or even end users like farmers etc.).
- (b) Develop a Climate Change Data Distribution Facility.
- (c) Develop hydrological modeling for improved water resource Management.
- (d) Training and Capacity Building

The Centre will provide all inputs required for impact assessment. These may be available climate data as well as model forecasts. With this input other organizations to work out the possible impacts, either jointly with or individually on the various sectors.

**Annex B**

Organizational Structure of the Proposed Centre



## Annex D

## NO. OF POSTS YEAR-WISE

S.No.	Category	Scale of Pay	Basic pay	Grade Pay	2008-09	2009-10	2010-11	2011-12	Total
1	Scientist - C	15600-39100	18750	6600	-	5	5	5	15
2	Scientist - D	15600-39100	21900	7600	-	6	6	5	17
3	Scientist - E	37400-67000	37400	8700	-	6	6	5	17
4	Scientist - F	37400-67000	40200	8900	-	4	3	3	10
5	Scientist - G	37400-67000	43000	10000	-	1	-	-	1
<b>Total</b>					-	<b>22</b>	<b>20</b>	<b>18</b>	<b>60</b>
<b>Technical (IT Support)</b>									
1	Equivalent to Sc. C	15600-39100	18750	6600	-	3	-	-	4
2	Equivalent to Sc. D	15600-39100	21900	7600	-	4	-	-	3
3	Equivalent to Sc. E	37400-67000	37400	8700	-	3	-	-	3
<b>Total</b>					-	<b>10</b>		-	<b>10</b>
<b>Administrative</b>									
1	Equivalent to Sc. E	37400-67000	37400	8700	-	1	-	-	1
2	Equivalent to Sc. D	15600-39100	21900	7600	-	2	-	-	2
3	Equivalent to Sc. C	15600-39100	18750	6600	-	2	-	-	2
4	Equivalent to Sc. B	15600-39100	15600	5400	-	3	-	-	3
5	Equivalent to JSO	9300-34800	12540	4600	-	2	-	-	2
<b>Total</b>					-	<b>10</b>	-	-	<b>10</b>
<b>Grand Total</b>					-	<b>42</b>	<b>20</b>	<b>18</b>	<b>80</b>

Minutes of the **"Brainstorming Workshop for the Development of a National Program on Climate Change Research"**, CSIR Science Center, New Delhi,  
June 01, 2007

A **"Brainstorming Workshop for the Development of a National Program on Climate Change Research"** was held at CSIR Science Center, New Delhi on 1st June, 2007. This Workshop was jointly organized by IITM, Pune/MoES, New Delhi, and it was attended by senior scientists and policy makers representing several ministries, departments and institutions. List of participants is attached herewith.

The Workshop began with the welcome and opening remarks by Dr. P.S. Goel, Secretary, MoES. He welcomed the Hon. Min. for ST & ES, Shri Kapil Sibal, and others present in the Workshop. Dr. Goel outlined the purpose of the Workshop and brought out several aspects of climate change, including the possibility of the present-day climate shifting to a totally different regime under global warming. And stressed as a consequence, there is a need for a coordinated and concerted effort in developing a national program on climate change involving all concerned ministries/departments/agencies/institutions. He also emphasized the need for establishing a dedicated center with a well focus on 'Science Issues of Climate Change' at IITM, Pune.

Dr. Goel's address was followed by a comprehensive presentation on 'National Perspective on International Issue' by Dr. Prodipto Ghosh, Ex-Secretary, MoEF. Dr. Ghosh briefly apprised the participants of all the major international bodies and protocols that exist and are relevant to Climate Change. He eloquently mentioned the issues of GHG abatement and their implications for India's development and economy. He also explained the mitigation games being played by the highly industrialized nations versus the developing countries. He mentioned of the general benefits of India taking up GHG emissions abatement as a policy through the introduction of energy efficient technologies etc. For this purpose, he suggested that India's Science Plan may include National Observational Networks, Economic Modules and Climate Parameterization Models.

Following the interesting presentation by Dr. Ghosh, the Inaugural speech was delivered by the Chief Guest, Hon. Min. Shri Kapil Sibal. He started his speech saying that 'the data shared by Dr. Ghosh suggests that the India's emission records and future projections are at safe levels and we are in good hands when it comes to dealing with the international negotiations'. He encouraged all concerned that we should be able to demonstrate to the world by 2012 that India is not contributing to the Global climate change. He expressed his happiness about India being a great beneficiary of the CDM projects.

Referring to the opening remarks made by Dr. Goel, Shri Kapil Sibal said the need of the

hour is to start investing more on the science of climate change in order to have greater certainty in the projected future. From a political point of view, he says, from whatever we might do at this juncture may not really reduce the global GHG emissions, as long as those who are emitting most are not brought under Kyoto Protocol. He cautioned that the global warming is not just a concern for India but is a problem for the entire globe and hence everyone should be held responsible in what they do to damage our Mother Planet. In this context, he cited a nice quote that 'We do not inherit the Earth from our ancestors but borrow it from our children'. He also quoted Mahatma Gandhi by saying 'There is enough for our need from the Earth but not probably enough for our greed'. He mentioned about the impressive growth in manufacturing sector and its increasing contribution to India's GDP. This can shift more and more people from the traditional agricultural sectors to the industrial ones. Also, the development pushes our demand for cement and steel upwards making the manufacturing and the resultant emissions to go up in the future. He opined that the material being used in manufacturing sectors, at the moment world wide, will undergo drastic change and more and more eco-friendly materials would be introduced. The western world with their technological and innovative advantage would determine the world markets on raw materials and hence it is time for us to catch up on the technology needed to counter this.

The honorable Minister expressed his desire that 'we need global effort to bring the industrialized countries to limit the emissions and to make them pay for what they have contributed to Climate Change so far'. Also, technology should be transferred from rich to poor nations with out any delay'. He feels this issue is not necessarily in the context of India but a serious global one. He urged his ministry to start thinking in these lines, in terms of sustainability, new technologies, invest money in advanced materials (for example, bamboo missions etc.). He posed questions like 'why cannot we change the way we practice agriculture in this country? Why should we use 1000 tons of water for 1 ton of grain production? He expressed his unhappiness about the communication gap between different ministries within India; as a result, the technologies developed by one ministry are not reaching the others. He continued to remind that it takes coal to get formed under the Earth several million years which we are trying to bum off in a few centuries and put all the carbon back into the atmosphere - can such a thing sustainable?

The honorable Minister further added that there is a danger of whole species getting vanished if there is a sudden change in climate as a consequence of our irresponsible actions. If we change the symbiotic relations between different species on Earth through man-made interventions it is going to be disastrous, and such issues are more important than the GDP growth. However, it is equally important to continue the growth trends we are experiencing of late to move more people out of poverty levels. What we need to come up is to find alternate sources of energy and invest in cleaner technologies. These could be far more sustainable in the long run. He pointed out that the amount of investment in

disaster preparedness and management is still very small. We have the capabilities to monitor and predict such events. But we need to increase the human resources to tackle this very important issue. MoES and MoEF should start looking into this issue jointly to generate a high quality human resource to come up with needed technologies. He finally expressed his happiness that these ministries are now working together and it should result in developing a permanent mechanism to address this issue. He also urged the audience to reach out to various sectors, industry and develop a central policy frame work to tackle this problem.

The Inaugural Session ended with a vote of thanks by Prof. B.N. Goswami, IITM.

### **Session I: Dimensions of Climate Change Program**

**Dr. Ramasami**, Secretary, DST, made a presentation on 'Climate Change: National Capacity Building'. He proposed the development of cost viable and affordable technology alternatives to those with high climate change potentials and advised that it is the most needed step for India as well as for sharing with nations. He also emphasized the need for capacity building in technology aspects. He lists the following priorities to address climate change research:

- Intra-network of CSIR laboratories, and network of Indian scientists and engineers
- Vegetarian conversion from non-vegetarian
- Creation of new Institutions in networking, and members as partners
- Generation of new research fund and creation of new framework to attract young talents for climate change research (CCR)
- Establishment of three new national centers with common but differentiated responsibilities within their respective capacities

**Dr. Andrew Reisinger** presented the highlighted the salient features of the first 3 working groups of the IPCC AR4 on "Summary for Policy Makers". He made the following suggestions for a coordinated program on CCR

- Projections of climate change at regional and local scales require nested models and statistical down-scaling.
- Impacts are location-specific and depend on complex interactions between climate and non-climate drivers; mapping of vulnerability requires multiple inputs
- Adaptation and mitigation are most effective if embedded in broader sustainable development programs.
- Effective development of science, technology, implementation, and coordination with policy frameworks, requires a multi-agency approach
- Integration with broader development initiatives to reap co-benefits of adaptation and mitigation and to manage trade-offs effectively

- Investment in human capacity to interact with global and regional climate change processes
- Implementation of research results relies on making the benefits and co-benefits of climate change research transparent and tangible to a broad range of end-users

**Prof. B.N. Goswami** provided a comprehensive assessment of the Science of Climate Change and identified certain outstanding key science issues and gaps in Indian research that require immediate attention. He cautioned that reliable answers to these science questions would be the key to the policy makers. He further indicated that credible answer to these questions require comprehensive ocean-atmosphere-biosphere modeling. He listed the strengths at international level and identifies gaps at national level. He raised an urgent need for a quantum jump in the computational capacities for better modeling, and trained manpower. He also raised the need for improved observational networks for realistic assessment of GHG emissions and the exact role of aerosols in the global and regional climate change.

**Dr. P. K. Aggarwal** discussed the Implications of Climate Change on India's Agriculture. He provided a glimpse of the global and regional implications of climate change on agriculture, based on IPCC AR4 reports, and listed below some of the issues that are relevant particularly to India.

- Productivity of most food crops would decrease due to increase in temperature and decrease in water availability. This would also increase fertilizer requirement which results in higher GHG emissions.
- Food trade is projected to be affected due to positive impacts on agriculture in Europe and North America, and negative impacts on South Asia and Africa.
- Increasing sea and river water temperatures are likely to affect fish breeding, migration, and harvests.

Dr. Aggarwal offered certain measures to increase the adaptive capacity of agriculture to climate change and identified ways to reduce GHG emissions from agriculture. His recommendations include 1) Formation of a Weather Watch Groups for all major crops in India 2) Establishment of National Agricultural Intelligence System 3) Improved land/resource use policy 4) Increased investment in adaptation research and 5) Improved accessibility of historical and real time data to researchers.

### Discussion on Session 1

**Prof. D.R. Sikka** suggested that while stressing the immediate need for identifying a suitable coupled model for assessing the impact of climate change on monsoon precipitation, he suggested the following

- Considering high sensitivity of crops during winter, good modeling strategy has to be evolved for better prediction of winter temperatures.
- Development of alternate technology to reduce use of fertilizers and regulate emissions to mitigate climate change impacts on agriculture production

Besides emphasizing the key issue of trained manpower development, **Dr. A.P. Mitra** pointed out the following for consideration while establishing the proposed CCR centre

- The absorbing and scattering aerosols need to be treated separately for better assessment of climate change impacts
- Inclusion of short-lived gases in the models while generating climate change scenarios
- Implementation of agency-accepted long-term plans for addressing the key science issues of CCR rather than Grant-in-Aid kind of support
- Initiate inter-laboratory programs for strengthening the Indian CCR
- Need for easy access of maps showing various components of climate system

In response to the above remarks and suggestions from the floor, **Dr. P.S. Goel** brought out the following points

- A comprehensive Agromet Advisory Forum being launched by the MoES
- Recruitment ban by the PM needs to be re-visited to remove the manpower crunch
- Future research should be well focused and job-oriented
- Launching of a MoD with IIT(D) on Atmospheric Science Course for human resource development.

### Session 2: India Focus

#### **Dr. A.P. Mitra**

Following a brief on the significant findings from the INDOEX on the transcontinental haze, Dr. Mitra summarized the role of the current research programs such as ABC, MAIRS. He projected the new sites for ABC program and plans for simulations of impact of ABC on agriculture, water and health. In this context, he mentioned that JARI has

agreed to act as nodal agency for impact analysis. He also highlighted the expected deliverables such as state-wise emission inventories of CO<sub>2</sub>, BC and CO under the framework of ABC.

### **Prof. V.K. Gaur**

Professor Gaur outlined, in his presentation, the objective and outcome of his recent researches addressed to quantifying the global carbon fluxes over India and the surrounding regions, carried out jointly with LSCE/CNRS France. He stated that the approach followed by his group exploited the relationship between the measurable atmospheric CO<sub>2</sub> concentration  $C(R^*, t^*)$  at a given space time coordinate, and the carbon flux around the globe  $F(R_k, t_k)$  through the atmospheric transport Green's function  $G(R^*, t^*, R_k, t_k)$ . The twin research objectives of this initiative have resulted in

- i) the establishment of an internet connected ultra high precision CO<sub>2</sub> concentration (~50-80 ppb) measuring system at the site of the Indian Astronomical Observatory in Hanle, Ladakh which has been operational since August 2005, together with flask samples systematically collected at Hanle and Pondicherry, and
- ii) the operationalization and testing of an atmospheric inverse transport model at C-MMACS for estimation of CO<sub>2</sub> fluxes  $F(R_k, t_k)$ . Based on the Green's functions analysis made by his group, he suggested establishment of additional continuous operating systems at Pondicherry, Andamans, Cheerapoonji, Sagar, Mt Abu, Pune / Alibag, Laksshadweep, Cape Comorin and in neighboring countries: Seychelles, Madagaskar, Rangoon.

### **Shri B. Mukhopadhyay**

Shri Mukhopadhyay presented a brief on "Observational Network and Needs" for strengthening the CCR in India. He narrated the current status of IMD's on-going and proposed observational networks. He also stressed the need for advanced experimental techniques such as Lidars, Radiometers for future CCR.

### **Dr. K. Krishna Kumar**

Dr. Krishna Kumar briefed about climate research activities at IITM using the HadCM3 and PRECIS models, and explained how these model outputs are being used by other research institutions to assess the impact of climate change on different sectors such as agriculture, water, pollution and health. He also stressed the need for augmentation of these research activities through more joint collaborations so as to derive more benefits to the country.

### **Dr. Tiwari, NPL**

Dr. Tiwari talked about the CSIR Global Change Network program that has been formulated under the 11<sup>th</sup> FYP and lead role of NPL and NEERI in it. He mentioned that the main elements of this project include NATCOM-II, ABC, modeling, impact assessment, observational facility and alternate technology development. He also mentioned that the project concentrates on role of trans-boundary pollutants and mega cities on climate system, vulnerability and adaptability analysis and comparison of model results with observations.

### **Prof. B.N. Goswami : Institutional Framework for the proposed Centre for Climate Change Research (CCCR or C<sup>3</sup>R)**

Prof. Goswami presented a proposal stressing the need for a dedicated Centre for Climate Change Research (C<sup>3</sup>R) at IITM, Pune. His presentation included the following

- Capabilities and infrastructure available with IITM to take up the lead role in the proposed C<sup>3</sup>R .
- Proposed Institutional framework with detailed science plan.
- In take of seed research scientists from IITM to begin with and subsequent development of trained manpower for augmentation
- Detailed road map for implementation and execution of C3R at IITM, Pune

### **Prof. U.R. Rao**

Prof. D.R. Rao made a brief presentation and stressed that the IPCC Report is correct in predicting general trend but contains lots of uncertainties in its detailed predictions due to various factors which are not clear. As an example, he brought out the importance of the role of galactic cosmic rays in global warming. He alluded to the fact that the high energy cosmic rays could modulate the low level cloud cover and could result in significant radiative forcing, a process not included in IPCC models. He stressed on the need for evolving our own answers to these science issues. In this context, a comprehensive and coordinated effort such as the proposed Centre at IITM is what is required, he opined.

### **Panel Discussion**

The scientific and policy making presentations were followed by a Panel Discussion which was headed by Prof. D.R. Rao. The issues relating to the Indian Climate Change Research and Needs were deliberated by the Panelists. The highlights of these deliberations by each Panelist are listed below.

**Dr. Mitra**

While strongly supporting the concept of a dedicated Centre for Climate Change Research to address the Science issues, he added that the following points should be addressed.

- A mechanism to create jobs and train youngsters in modeling and observational techniques
- Involvement as Indian partners in International Programs such as ABC and MAIRS
- Need for undertaking observational programs like ABC with funding from the national coordinating cell of the ministry or directly by the proposed center.
- Need for drastically changing the present highly inhibiting mechanisms for recruitment of scientific manpower. He also feels only then we can attract needed highly qualified and trained manpower for the purpose.
- Remove mismatch between models and observations that arise mainly due to inaccurate emission estimates
- Constitute Panels consisting of senior scientists from different Institutions and organize frequent meetings

**Prof. Rao**

- Suggested constitution of a National Committee ("Think Tank" concept) to oversee the participation of different Institutions and Groups in major International programs. He opines that it will provide necessary intellectual inputs to the center.

**Prof. Goswami, IITM**

Regarding the point raised by Dr. Mitra on manpower training, Prof. Goswami mentioned that,

- A job linked training program supported by MoES is being worked out. It will be linked with an attractive Earth Science Fellowship to attract best students from engineering as well as science streams. The program will be well advertised so that some bright young fellows can make career decisions.
- A comprehensive Training program will be worked out by IITM in collaboration with top educational and training Institution such as the IISc.

**Dr. Ghosh, MoEF**

- Objectives of National Program should include (i) Planning, (ii) GHG Mitigation technologies, (iii) International negotiations and policy and (iv) Long-term perspective

### **Prof. Sikka**

- Expressed full support to the creation of proposed C3R at IITM, Pune, and emphasized urgent need for HPC for undertaking multiple scenarios using fully coupled models.
- Integrate IMD's National Climate Centre into the framework as a consortium.
- Select a particular suitable model and involve several groups in India to validate and improve the model for the Indian region as a consortium mode with IMD and Pune University
- Easy data accessibility from IMD

### **Prof. Gaur, C-MMACS**

Strongly supported the establishment of the proposed Centre of Climate Change Research at IITM, Pune.

- However, he emphasized the imperatives of sustaining a very high level of scientific rigour and analysis at this Centre in view of the ineluctable requirements of its endeavors to be commensurate in every detail with global endeavors elsewhere.
- Accordingly, he advised that the Centre should be so structured as to have the benefit of an imaginative group of active scientists constituting a Think Tank, as well as its own specific Program office entrusted with the responsibility of catalyzing, supporting and critically sustaining a wide area of collateral research and development activities collaboratively with national academic and research institutions as well as those in neighboring countries, specially central and southeast Asia.
- In particular, he suggested that the Centre should itself organize Research groups/activities manned by physicists, chemists, engineers and computer scientists of the highest caliber as given in A below, whilst the Program Office should have the responsibility of handling the activities under B:

#### ***A. The Centre's core research and analytical programs:***

1. Establish and operate a few (2-4) continuously running key observatories and catalyze the establishment of about 25 others (a few continuously running plus most flask collection centers), collaboratively with academic/research institutions in India and neighboring countries and, thereby instituting a self evolving mechanism for high quality manpower generation.
2. Establish an ultra high precision analytical laboratory for measuring GHG concentrations. This should be done meticulously and with great deliberation so as to ensure quality and WMO accreditation. It may best be done in 2 phases beginning with Gas Chromatographs followed by Mass Spectrometers and Radon measurements, in professional collaboration with NCUPRL respectively.
3. Establish a state of the Art Computing facility modeled to grow into the Indian counterpart of the Geophysical Fluid Dynamical Laboratory (GFDL) of Princeton with extensive modeling activities based on several GCMs. Scientific activities of

the group would include testing of hypotheses and models, evaluating the quality of solutions, producing new desired codes etc. especially targeted towards progressive evolution of coupled AOGCM's incorporating the Carbon cycle and other effects representing significant radiative forcing that may be indicated in the future.

4. To create facilities for Visiting Fellows from across the world to participate and contribute to a progressively expanded global endeavor commanding world attention.

***B. The Program Office of the Centre would, complement the Centre's in-house activities with the following:***

1. Help articulate desirable R&D activities aimed at mitigating the adverse impact of Climate Change as well as devising/designing policy options, and identifying and persuading appropriate professional groups to implement these programs (e.g., energy conservation and efficiency: Catalysis Research and alternate design of more efficient machine systems; carbon sequestration S&T; quantification of radiative forcings by different climate implicated agents, especially aerosols, devising policy frameworks for guiding India's national policy and programs on global issues of the Environment and Climate Change).
2. R&D aimed at advance identification of possible future adverse happenings e.g. forestalling carbon immobilization from shallow earth archives: peat and methane beds, gas hydrates etc.
3. To develop, sustain and progressively enhance the international interface particularly with developing countries.

**Prof. Bhat, IISc**

Strongly supported that a dedicated Centre for addressing the Science issues of Climate change is. the need of the hour and as such the Proposal to set up such a Centre is welcome. He further added,

- Quantification of forcings on climate change is required.
- ICRP research activities of DST did not address the Climate Change issues and need revision
- Aerosol-cloud interactions including their micro-physics should be the priority
- Assess the changes expected in the hydrological cycle rather than just in rainfall or temperature
- Some basic research to improve climate models is very much needed. In that context, the study proposed by IITM on cloud physics and interaction between convection and environment is an interesting development.

**Dr. Bhatia, IMD**

- IMD' s extensive databank on various meteorological parameters
- IMD' s reports on monsoon prediction
- Observational networks be improved not only in India but also in the adjoining regions

- IMD should have periodic calibration and check on performance of sensors for the stability of its long-term data products - suggestion from Prof. Rao
- IMD should develop a good model for manpower deployment and introduce the Ph.D. Program to enhance its research capabilities in addition to the operational skills

#### **Dr. Dutt, ISRO**

- The ISRO endorses the establishment of C<sup>3</sup>R at IITM, Pune and assured its support particularly in the area of land cover and land-use change scenarios for better modeling of climate issues
- Technological support for developing agro-meteorological towers coupled with AWS for the proposed network under the C<sup>3</sup>R
- Extend support for establishing ABL, lidars, MWRs and environmental observational network observations for proposed climate studies by the C<sup>3</sup>R

#### **Dr. Bohra, NCMRWF**

- Models being run at IITM and NCMR WF should be used. for future climate predictions
- Need for a holistic climate system modeling
- Develop a GCM suitable for India for climate studies
- Synergize the efforts of the NCMRWF for evolving better approach for climate research

#### **Dr. Leena Srivatava, TERI**

- IPCC projections involve uncertainties but they provide ways to improve upon
- Need to consider other Institutions that are involved in NATCOM process while formulating a national program
- Identify different Institutions to bridge the existing gap areas in the field - A model of NATCOM Cell at MoEF may be considered.
- She also made the point that if there is a Scientific Steering Committee (SSC) established, that can act as a think tank to identify important projects that could be taken up for research,  
then the numerous institutions involved in climate change research in India should be given an opportunity to work on such projects, individually or jointly. The SSC may also decide to allow one or more institutions/consortia to work on a particular aspect of the climate change challenge if it thinks necessary.

#### **The Panel made the following recommendations:**

- There is a general recognition that climate change is a happening thing and needs immediate attention.

- It is recognized that the nation is not ready with reliable answers to many outstanding S&T issues concerning climate change. Credible answers to these questions are essential for effective negotiations at international forums.
- The present efforts in India to deal with climate change issue are not only inadequate but also lack integration and networking.
- The panelists and participants of the workshop unanimously recommend that a coordinated National Program for climate change research should be evolved. It was suggested that this may be achieved by setting up National Centres to address different issues (e.g. Science Issues, Technology issues, Impacts, mitigation and policy issues) and by establishing a coordinating mechanism.
- As a part of such a National Program, the proposal from MoES to establish a dedicated Center for undertaking research on Science aspects of Climate Change at IITM, Pune, has been strongly endorsed by the panelists and participants. While the existence of a critical mass of core scientists with experience in both theoretical and modeling aspects of climate science at IITM provides the basis, it would require major investment in physical and computational infrastructures as well as humane resources for the success of such a Centre.
- As the science program involves observations as well as modeling, the Centre at IITM is to network with other Institutions in the country involved in observations (e.g. NPL, NIO, CMMACS (CSIR org.), IMD, PRL, SPL (ISRO org.), IISc, IIT/D, IIT/K, IIT/Kgp (Universities) for a comprehensive observation program). For modeling, it may collaborate with institutions like IISc, IIT/D, NCMRWF etc.
- It is recommended that for the Climate Change Program, a Program Office may be set up at the MoES. The Program Office will not only mentor the Centre at IITM, it would also proactively support and fund projects on all aspects of Climate Change. It would also evolve a mechanism to network programs on climate change across Ministries.
- A recommendation emerged from the panelists is that a Scientific Steering Committee (SSC) consisting of eminent scientists and professionals may be set up by MoES for the Climate Change Program. The SSC will act as a 'think tank' for the Ministry and identify important projects to be taken up and help Program Office to implement them. It will also review and provide intellectual input to the Centre at IITM.
- The Panel also recognized the current inadequacy of human and infrastructural resources needed for addressing this very important national issue and strongly recommends a quantum jump in the investments on human resource development and infrastructural facilities.

**List of people participated in the workshop**

Shri Kapil Sibal, Hon Min for ST&ES  
Prof UR. RAO, ISRO  
Dr. A. P Mitra, NPL  
Dr. Prodipto Ghosh, MoEF  
Dr. T. Ramasami, DST  
Prof. S. K. Tandon, DU  
Prof. D.R. Sikka, New Delhi  
Dr. R C Bhatia, DG, IMD  
Prof. V. K. Gaur, IIA  
Prof. U C Mohanty, IIT/D  
Dr A.K. Bohra, NCMRWF  
Dr. P. K. Aggarwal, IARI  
Dr. Leena Srivastava, TERI  
Dr. Andrew Reisinger, IPCC, New Delhi  
Dr. M.K. Tiwari, NPL  
Dr. G.S. Bhat, IISc  
Dr. S. Dutt, ISRO  
Representative of CWC  
Dr. P.S. Goel, MoES  
Prof. B.N. Goswami, IITM  
Dr. K. Krishna Kumar, IITM  
Dr. R. Krishnan, IITM.  
Dr. P.C.S. Devara, IITM  
Dr. Swati Basu, MoES  
Dr.B.Mukhopadhyay,IMD  
Dr. Akhilesh Gupta, Adv. to the Min. S & T

**SUMMARY AND RECOMMENDATIONS OF  
BRAINSTORMING WORKSHOP FOR THE DEVELOPMENT  
OF A NATIONAL PROGRAM ON CLIMATE CHANGE  
HELD BY THE MoES ON 1 JUNE 2007 AT NEW DELHI**

**1. Preamble:**

Global change induced climate change has become a major threat to present day society because of its adverse impacts on ecosystem, economic system, agricultural productivity and water resources in global as well as regional basis. The recent report of the IPCC (AR-4) has recognised with very high confidence (atleast 90% probability of being correct) that human activities have caused the planet to warm in the last 200 years by about 1°C and this trend is likely to cause average global warming of around 3°C (range of 2°C to 4.5°C) with the doubling of carbon dioxide content in the atmosphere compared to the pre-industrial level. Observational studies over India have also shown warming of about 0.5°C per 100 years on an All India average basis though pockets of higher values and even cooling exist over different parts of India. Future projections of climate change using global and regional climate models, run by IITM with different IPCC emission scenarios, indicate temperature changes of about 3 – 5°C and increase of about 5-10% in summer monsoon rainfall. It is also projected that number of rainy days may decrease by 20 to 30% which would mean that the intensity of rainfall is expected to increase. Extremes in temperature and rainfall also show increase in their frequency and intensity by the end of the year 2100. Recent work done in the daily rainfall for over 50 years show similar trends in extreme rainfall. Crop models run with such scenarios also show fall in food production per acre in India by about 20%. Further hydrological models show fall in India's water resources which when combined with the recession of Himalayan glacier would pose a serious threat to the food and water security of the rising population of India.

There is also possibility of enhanced vulnerability of the large population of India, habitating the coastal zone, because of rise in sea-level and greater frequency in high intensity tropical cyclones striking India's large coastline of about 7500 km. Studies on the magnitude of climate change, its science impacts, mitigation and adaptation have been pursued under several scientific establishments in India. Some of the studies were even conducted under the Ministry of Environment and Forest sponsorship formed basis of India's First National Communication (NATCOM) on climate change and are progressing at present under the second NATCOM.

**2. Summary of the Workshop on 1.6.2007**

The workshop on 1<sup>st</sup> June 2007 was addressed by scientists of several organisations including the Ministry of Environment and Forests, MoES, DST, IMD, DOS, IITM, CSIR, IIT Delhi, ICAR and other senior scientists of the country who reviewed the work being done in India on the science of climate change (modeling and rising emissions of GHG and GHCs and aerosol monitoring) impacts (agricultural, water resources, human health etc.). Mitigation strategies (Technology alterations carbon sequestering and monitoring of carbon dioxide flux). Adaptation to climate change etc. The need for organising a National Program on climate change to cover different aspects

like science of climate change, Monitoring of climate change, Impact Assessment, Adaptation and Mitigation became quite clear from different presentation. The workshop also discussed a proposal put forth by IITM to establish an autonomous centre under its ambit with funding and guidance from MoES for Climate Change Research. The proposal envisaged a budget of Rs.117.00 crores in the next 5-years to be used for physical Infrastructure (Laboratory and office space and computer support), Manpower, Manpower development and Running cost etc. The program involves observation, modelling, learning from palaeoclimate studies and applications. As IITM is already having three divisions (the Division of Climatology and Hydrometeorology, Division of Climate Modelling and Division of Forecasting Research) which have been pursuing some studies in climate change related issues at the Institute, IITM proposed to provide a nucleus of about 10 scientists for the new centre to initiate an organised activity which could be supplemented by providing further scientific manpower and infrastructural support etc. under the funds requested from the MoES.

At the end of the Brainstorming Session a Panel Discussion was organised under the Chairmanship of Prof. U.R. Rao to make recommendations about organisation of a National Program in climate Change Research with special reference to the IITM proposed program of establishing a centre for Climate Change Research (CCCR).

### 3. Recommendations of the Panel

There was a recognition that India must evolve a comprehensive National Program to address issues relating to climate change covering science of climate change mitigation (Advanced Technology adoption) (**Modelling Monitoring and Emission Inventories**). Adaptation and even addressing questions about India's case at International for its need to alleviate poverty even in the face of threats by the rapid development of India. Climate change is not only a scientific problem but also involves ecological, social, economic, political and even diplomatic issues. Therefore it is important to study how to resolve conflicts between developing economy of India and protecting the limited natural resource for the rising population.

The above issues involve several important aspects for which expertise is available in different organisation in the country and they would need support to enhance their work. IITM can engage itself on issues connected with climate change science. Different Ministries of the Govt. of India (MoEF, DST, DOS, MoES) may continue their respective efforts on climate change issues. MoES, being the nodal agency for Atmosphere and ocean science, may take up the responsibility of bringing synergy between the work of other organisations so that a national expert opinion is evolved through periodic discussions to be organised under their umbrella. Such an arrangement will enable the nation to with outstanding S&T issues concerning climate change as the present efforts in India are not only fragmented but also need integration and networking.

Whereas the IITM may not have the expertise to address to all issues involved in climate change, it is well suited to launch a major effort in Research issues on climate change science particularly in relation to Modelling and in cooperation with IMD (National Climate Centre, Pune) on Climate data and analysis environment monitoring centre of IMD at New Delhi which CCCR may begin its activities with nodal scientist provided by the IITM. They may add about nine scientists in the next 5years. The project

may be reviewed in 2011-12 to further augment its activities for the next 5 years, if needed. DST may establish a centre for Adaptation of Technology to combat climate change and CCCR of IITM may provide scientific support to the DST centre.

IITM (CCCR) may workout a mechanism to network many institutions working in climate change issues (Science, Technology, Adaptation, Mitigation, Policy response etc.). For this purpose IITM may initiate a comprehensive study to prepare an expert report on the Assessment of climate change issues in India. This first is needed partly for consolidated planning).

MoEF would serve as the nodal agency for international response to climate change Issues and Policy Initiatives. IITM may provide inputs for climate change science to MoEF.

All the major efforts at MoES/IITM/DST and MoEF may work closely towards an integrated approach to climate change issues in the context of global and regional problems likely to be faced.

MoES may establish a program coordinating office at the MoES to develop and fund climate change Research Issues and a committee to monitor and support the program may be set up by them.

Recognizing the current inadequacy of human and infrastructural resources needed to address the very important national issue the panel is of unanimous view that a quantum jump is needed in our investment on training human resources and infrastructures. Climate change need about 5 years to begin contributing

IITM besides involving IMD and NCMRWF in its climate change science issues may also involve University of Pune (Deptt. of Atmospheric Physics, Space Physics and Environmental Science). They may also build partnership with IIT Mumbai, IIT Kharagpur, IIT Delhi, IISc Bangalore and Dr. Jyoti Parikh, Institute at Mumbai and Dr. Shukla's groups at IIM Ahmedabad as well as CSIR (NPL Delhi and NIO Goa), ISRO Bangalore and INCOIS Hyderabad. Thus a consortium of organization could be promoted by IITM to consolidate the work relating to climate change. IITM in its CCCR may provide visiting scientists program in which scientists from other organizations in India and other countries may work on specific problems to spread the Climate Change Research Program.

MoES may, besides providing super computing facility for Climate Science Research at IITM, Pune also provide such money immediately to IITM to spearhead the recommended program.

MoES may constitute an Apex Scientific Steering Group to guide the CCCR which may meet twice in year to review and advise on the implementation of the CCCR program and its further augmentation.