Climate Research in India : Progress and Vision for 2030

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1. History of Global CC research

The World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP) jointly set up the Intergovernmental Panel on Climate Change (IPCC) in the year 1988 with the aim of preparing science based assessment on all aspects of climate change and its impacts and developing realistic response strategies. The scientific evidence brought up by the first IPCC Assessment Report of 1990 underlined the importance of climate change as a challenge requiring international cooperation to tackle its consequences. Since then the IPCC has delivered on a regular basis the most comprehensive scientific reports about climate change produced worldwide, the Assessment Reports. So far IPCC has brought out 5 assessment reports. The Working Group I report of IPCC's Sixth Assessment has already been released. Remaining reports are expected to be finalized by next year.

2. History of India's CC research

India too responded to the global concerns for the systematic research in climate change areas soon after the first assessment report of IPCC was published in 1990. Fortunately by this time India had already initiated some research initiatives. The country has had the fortune of having over 100 years of systematic meteorological observations. Recognising the importance of climate research in the country the Department of Science & Technology initiated an extra-mural funding programme called *Indian Climate Research Programme (ICRP)* in 1997 immediately after the 2nd Assessment report of IPCC was released in the year 1995. The ICRP focused on the research priorities in understanding climate variability at different time scales and its impact and consists of analysis of observational data from ground-based, ship-based and satellite-based measurements; modelling studies with coupled ocean-atmospheric general circulation models and identification of the climate component of agricultural productivity, impact of climate on environment, global warming and climate change etc. There were several Multi-disciplinary and multi-institutional field observational programmes also conducted in the

Indian sub-continent region during this period. These included Monsoon Trough Boundary Layer Experiment (MONTBLEX); Land Surface Process Experiment (LASPEX); Bay of Bengal Monsoon Experiment (BOBMEX), ARMEX (Arabian sea Monsoon EXperiment) and Indian Ocean Experiment (INDOEX).

Under Intensive Research in High Priority Areas (IRHPA) programme of DST a Global Climate Modelling Project was supported at Indian Institute of Tropical Meteorology (IITM), Pune to develop a general circulation model (GCM) to predict the Climate at seasonal scale. Also under IRHPA, a Centre on Global Change was positioned at National Physical Laboratory (NPL), New Delhi to study the Green House Gas emissions and related activities. The IPCC adopted this Centre's Methane budget estimates for India. In order to understand the role of Ocean in Climate variability, in particular relating to the monsoon phenomena, DST supported monitoring of Oceanic region surrounding India using Ships of Opportunity as Indian contribution to the international Tropical Ocean Global Atmosphere (TOGA-I) Program.

However, unlike western world, India remained short of resources to position a sophisticated infrastructure for climate change research until the end of 20th century. The number of climate change researchers and analysts in India was relatively small - the number of researchers involved on a continuing basis on all climate-change-related activities was less than a hundred in those days. There was also a relatively clear institutional division between those working in the realm of the physical and natural sciences and those working on policy related issues. If we classify the institutions that are involved in the climate change issues, we see that the largest single disciplinary groups of climate change researchers in India were climatologists and meteorologists. The number of institutions working on climate change research could be counted on fingers. Many of the scientists or groups work at these institutions in a relatively independent fashion, though there are occasions when they have successfully collaborated towards common goals, like the Indian Methane campaign (1991) that demonstrated a lower level of emission from Indian paddy cultivation.

3. CC Research initiatives in early 21st century

Soon after 3rd Assessment Report of IPCC was released in 2001, DST took initiative to build an International Centre for S&T Capacity in Climate Change and organized several workshops that included a side event at the 8th

Conference of Parties (CoP-8) in New Delhi in the year 2002. A Centre for Climate Change Research (CCCR) was eventually established as part of Indian Institute of Tropical Meteorology (IITM), Pune in 2009. In the mean time responding to 4th Assessment Report of IPCC (AR4) brought out in 2007, India released its National Action Plan on Climate Change (NAPCC) on 30th June 2008. The NAPCC contained some major initiatives that included launch of 8 national missions on climate change. These include;

i. National Solar Mission (NSM)
ii. National Mission for Enhanced Energy Efficiency (NMEEE)
iii. National Mission on Sustainable Habitat (NMSH)
iv. National Water Mission (NWM)
v. National Mission for Sustaining the Himalayan Eco-system (NMSHE)
vi. National Mission for a Green India (NMGI)
vii. National Mission for Sustainable Agriculture (NMSA)
viii. National Mission on Strategic Knowledge for Climate Change (NMSKCC)

Out of these 8 missions, 4 of them viz, NSM, NMEEE, NMSH and NMGI focused on mitigation; 3 of them viz., NMW, NMSHE and NMSA relate to adaptation initiatives and 8th Mission (NMSKCC) exclusively dealt with carrying out dedicated research in climate change areas to develop strategic knowledge.

India is witnessing expansion of climate change research initiatives launched by various government ministries/departments as part of implementation of national missions on climate change under National Action Plan on Climate Change. These research initiatives cover programmes in all the three areas of CC viz., science, adaptation and mitigation. The ministries/departments which spearhead these programmes include; Department of Science & Technology; Ministry of Earth Sciences; Ministry of Environment, Forests and Climate Change; Ministry of Agriculture; Ministry of Water Resources, River Development & Ganga Rejuvenation; Ministry of New and Renewable Energy; Ministry of Power; Ministry of Urban development; etc. A large number of institutions and scientists are part of this multi-ministerial research network.

4. Climate Change Research Initiatives by DST under NAPCC

The Department of Science & Technology, Ministry of Science & Technology was entrusted with the responsibility of coordinating two out of these eight national missions on climate change. These are: (a) National Mission for Sustaining Himalayan Ecosystem (NMSHE) and (b) National Mission on Strategic Knowledge for Climate Change (NMSKCC). Both these missions were launched with broad objectives of building S&T Capacity for sustenance of Himalayan Ecosystem and for developing strategic knowledge system

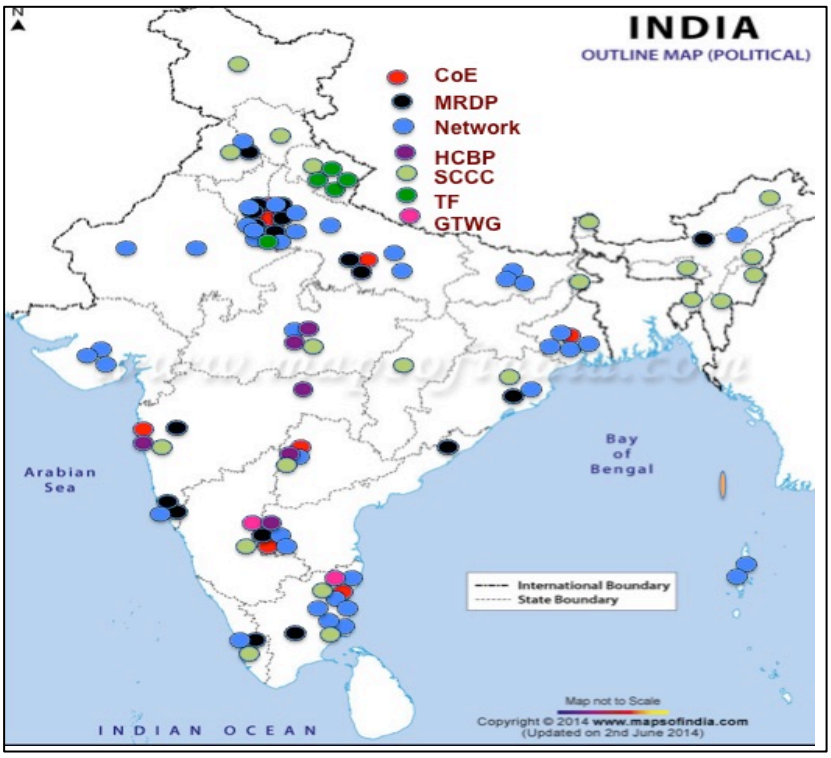
Both NMSHE and NMSKCC were initiated during 2011-13. There has been a good progress achieved under both the missions since then. Some of the major achievements under the two missions are summarized in the table below:

National CC Mission	**Institutional mechanism established**

NMSHE	1. A Centre of Himalayan Glaciology at Wadia Institute of Himalayan Geology, Dehradun; 2. 6 Thematic Task Forces anchored around 6 lead institutions viz., Wadia Institute of Himalayan Geology (WIHG), Dehradun; National Institute of Hydrology (NIH), Roorkee; GB Pant National Institute of Himalayan Environment and Sustainable Development (GBNIHESD), Almora; Wildlife Institute of India (WII), Dehradun; Jawaharlal Nehru University (JNU) and Institutions of Indian Council of Agriculture Research (ICAR); 3. 3 Centres of Excellence, one each at Kashmir University (Glaciology), Sikkim University (Water Resources) and Tezpur University (Forest ecosystem and biodiversity). 4. 8 Major R&D Programmes in different thematic areas 5. 18 Projects as part of 6 State Research Network programmes 6. State CC Centres in 12 out of 13 Himalayan States/ UTs viz., J&K, Himachal Pradesh, Uttarakhand, Arunachal Pradesh, Assam, Nagaland, Manipur, Mizoram, Meghalaya, Sikkim, Tripura and West Bengal. Efforts are being made to establish a SCCC in the 13th Union Territory in Ladakh. 7. An Inter-University Consortium of 4 universities viz., Kashmir University, Srinagar; Jammu University, Sikkim University and Jawaharlal Nehru University, Delhi and 8. An Indo-Swiss Capacity Building Programme in glaciology and related areas.

NMSKCC	1. 12 Centres of Excellence one each at IISc, Bangalore (2 phases); IIT Bombay (2 phases); IGCS, IIT Madras (2 phases); ICRISAT, Hyderabad (2 phases); IIT Delhi; IIT Kharagpur; BHU, Varanasi and National Institute of Malaria Research, Delhi 2. 23 Major R&D Programmes at NIO, Goa (2); NBRI, Lucknow (2); IARI, Delhi; Delhi University; TNAU, Coimbatore; IIT, Delhi (2); BSIP, Lucknow; IRMA, Anand; Allahabad University; IISER, Pune ; CUSAT, Cochin; Andhra University ; IIT Guwahati ; IIT Bhubaneshwar ; IISER Mohali; IRADe, Delhi; 3. 15 State Climate Change Centres in Madhya Pradesh (2 phases), Punjab (2 phases), Chattisgarh, Karanataka, Kerala, Puducherry, Tamilnadu, Telangana, Maharashtra, Orissa, Haryana, Gujarat and Bihar; 4. 8 National Network Programmes: 2 National Network Programmes in the first phase (CC & Human Health and Climate Modelling) and 4 Network programmes in the second phase (CC & Human Health, Climate Modelling, CC & Coastal Vulnerability and CC & aerosols); 2 network programmes in 3rd Phase (Urban Climate and Glaciology) 5. 7 Human Capacity Building Programmes one each at Administrative Staff College of India (ASCI), Hyderabad; Indian Institute of Public Administration (IIPA), New Delhi; Tata Institute of Social Sciences (TISS), Mumbai; Indian Institute of Forest Management (IIFM), Bhopal; Ashoka Trust for Research in Ecology and the Environment (ATREE) Bangalore and Visvesvarya National Institute of Technology (VNIT), Nagpur; 6. 8 Global Technology Watch Groups (GTWGs) led by National Institute of Advanced Studies (NIAS), Bangalore; IIT Madras and TIFAC, Delhi; 7. Indo-US Fulbright-Kalam Doctoral and Post-Doctoral Fellowships in Climate Change (annually 6 fellowships)

The figure 1 below give locations of various programmes/projects initiated under two missions.



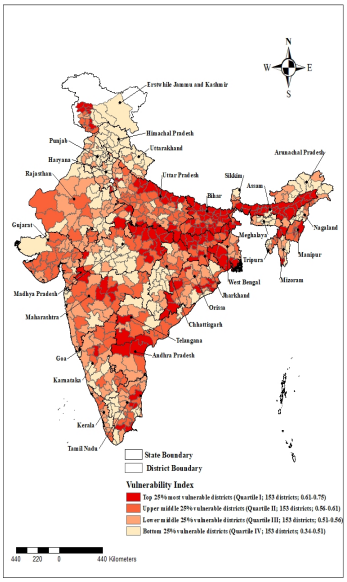
During past 5 years the DST-sponsored programmes have made a significant impact and resulted in a large number of useful publications in national and international journals. Over 2000 research publications have come out of these programmes so far, out of which a large numbers are in international journals of high impact factors. About 120 new techniques have been developed as part of programmes under two missions. Nearly 1500 scientists, experts and students and 250 institutions in the country have been associated with climate change programme of DST. Nearly 250 PhD and PG students have been enrolled as part of two missions in different projects. State CC Centres conducted 250 training programmes wherein 50,000 personnel were trained. In addition, missions supported 40 national level events wherein over 2000 participants benefited. As many as 1,50,000 people were given exposure about climate understanding as part of public awareness.

5. Some key results from recent research initiatives

a. All India CC Vulnerability Assessments

An all India climate vulnerability assessment was undertaken involving scientists at India's premier academic institutions like Indian Institute of Science (IISc), Bangalore and Indian Institutes of Technology (IITs), Mandi and Guwahati along with scientists from several institutions at the 29 States

and Union Territories of India. The major outcome of the study was the ranking of all the 29 states and 690 districts of the country in terms of their adaptive capacity to meet the challenges of climate change. Vulnerability Assessment and Ranking of 29 States of India



b. Mapping of Risk to Hydro-climatic Extremes

A detailed analysis of the social vulnerability to hydroclimatic extremes for the past two decades using a robust data envelopment analysis (DEA) framework was undertaken. Social vulnerability appears to have decreased over past decade, primarily due to an increase in literacy rate and conversion rate of marginalized groups to main working population, and a decrease in child population due to use of birth control. Contrarily, with an increase in probability of occurrence of hydro-climatic hazards over significantly large portions of India, agencies are expected to benefit from these maps to differentiate whether the risks at local levels are being driven by increases in social vulnerability or by hazards.

c. Glaciology Research: Glacier retreat, loss of mass, impact of CC

As part of climate research supported by the Department of Science & Technology under National Mission for Sustaining the Himalayan Ecosystem, some good results have come up. Some of these results are quite interesting and provide better understanding of present state of melting of Himalayan glaciers.

d. Impact of aerosols on altering frequency, intensity and duration of rainfall extremes

A study on aerosol mediation of precipitation extremes shows both suppression through atmospheric stabilization and enhancement through cloud invigoration. Under high aerosol build up during dry spell makes dry spell drier and following wet spell wetter.

A significant & consistent land-ocean contrast of aerosol cloud interaction (*aci*) observed over Indian region in all seasons. Soluble aerosols under ample ambient moisture & atmospheric convection strengthen positive *aci* over ocean. Dust & slightly soluble organic aerosols in moisture scarce non-convective system show negative *aci* over continental regions.

e. Spatio-temporal shift in heat waves and declining trend in diurnal temperature range

Spatio-temporal shift in heat waves was observed over India (1950-2016) with increasing trend over north-western, central, and south-central India. Declining trend in diurnal temperature range (DTR) was observed over different agro climatic zones of India in recent warming period of 1991-2016. Significant decline in DTR was observed over north-west, parts of Gangetic plain, north-east, and central India owing to much increase in min. temp than max. temp and decline in solar radiation

f. A new understanding about El-Nino relation with droughts in India

Not all El Ninos cause droughts and not all droughts are caused by El Nino. These two types of monsoon droughts are different not only in their oceanic markers, but also in their seasonal evolution. Rather than a signature in the Pacific, surface temperatures are observed to be anomalously cold in the North Atlantic during non El Nino droughts. In El Nino droughts, once rainfall deficit sets in early in the season, around mid-June, it progressively gets worse; by mid-August, the entire country is in large deficit and there is no going back. In non El Nino droughts, there is an initial moderate deficit in June. During mid-July to mid-August, the monsoon in fact shows signs of recovery. However, around the third week of August, the

buildup of deficit begins yet again and, within 3 weeks, nearly the entire country is covered in deficit.

6. The Way Forward

India has over the years built a strong climate change research base in terms of number of quality researchers, long term data and infrastructure. The Climate Change Programme of DST has achieved considerable progress during past 7 years. Plans are afoot to strengthen the programme by building human and institutional capacities, developing greater linkages among the institutions and widening the network of researchers. The programme identified 6 key priority areas for supporting climate research in the country during next 5 years. These include;

a. Glaciology
b. Climate Modeling
c. Urban Climate
d. Exteme Events
e. Aerosol studies
f. Himalayan ecosystem studies

A detailed plan of action is being developed on each of these themes for the country with possible collaboration at the national and international level. Brainstorming sessions are being planned to develop appropriate strategies and plan for these initiatives.

A detailed description of progress made by India in climate research and vision for future will be made in the presentation.