INDIAN CENTRE FOR CLIMATE AND SOCIETAL IMPACTS RESEARCH

Annual Report 2008 – 2009

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Vision

An integrated, multidisciplinary approach to research in the science of climate evolution and in societal adaptation to climate evolution is necessary for socio-economic and political stability of the global society in the 21st century.

Goals

Research Goals

Development of methodologies for assessment of climate variability and changes in western India at sub-seasonal to decadal time scales due to natural variability and human-induced changes, including global warming, and their societal impacts, using observations and models.

Understanding of climate related societal issues by means of inter-disciplinary (both at national and international levels) association; and development of techniques and technology for Earth System observations and modeling.

Education Goals

Education and training programs for high-school to post-graduate college teachers, public and private sector officials, on Earth System Science (ESS) and societal impacts of climate variability and changes, including global warming.

Ph.D. program for education and research in ESS and societal impacts.

Applications and Outreach Goals

Generate ESS and societal impacts data and information systems for farmers, water managers, public health officials, other stakeholders, and policymakers.

Create public awareness to these issues through exhibition-cum-experiments laboratory, and video and TV programs.

Board of Directors

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Foreword

I am very happy to present to you the first annual report of the Indian Centre for Climate and Societal Impacts Research (ICCSIR). It is a proud moment to showcase ICCSIR's achievements approximately one year after it was founded.

The combination of monsoon variability and changes and their societal impacts is unique in western India. This region is also home to approximately one-quarter of India's population. Because of the large number of people and variety of sectors affected, monsoon variability and change greatly influence the economic, business and political landscape of this region.

This region encompasses several climate zones from desert in the north to very humid in the south. Associated with sub-seasonal to multi-decadal variations of the monsoon front, depressions, and cyclones are droughts, floods, and intense rainfall events.

Highly variable water availability is the most serious problem for western India's agricultural production. In addition to climate variability, encroachment of sea water due to variable/rising sea level along the coastline also adversely impacts the productivity of coastal agricultural lands. Weather, climate, and ocean variability also influence fisheries. Additionally, weather and climate variability also influence vector- and water-borne diseases. These already-acute climate impacts can be further exacerbated in the coming decades by potential human-induced climate changes and altered climate variability due to such climate changes. Therefore, there is an acute need for a climate and societal impacts research, education, and applications effort focused on western India. It is very important to build research, education, and applications capacities in a phased approach.

In order to define a programme to address these issues, an international workshop was held in February 2007 in the Nirma University of Science and Technology in Ahmedabad. The workshop was made possible by the University's generous support and Vice Chancellor Dr. N.V. Vasani's encouragement. The workshop was co-sponsored by Department of Science and Technology of the Government of India and the National Science Foundation of the U.S.A. The workshop was attended by approximately 40 scientists from India, the U.S.A., and Japan; and was inaugurated by Shri Narendrabhai Modi, the Honorable Chief Minister of Gujarat. A plan to establish a centre of excellence was prepared based on recommendations from the workshop; the plan was reviewed and revised by the Scientific Advisory Committee in May-June 2007 and further refined in a meeting consisting of Shri Ashwin Shroff of the Excel Group, Shri Mahendra Patel of the Mamata Group, and several educationists and senior officials of Gujarat Government in August 2007. Finally, ICCSIR was founded in August 2008 as a non-profit, public-private partnership organization incorporated under Section 25 of the Companies Act (1956) of the Government of India.

The founding of ICCSIR comes at the time when awareness and importance of the environment in general and climate change in particular are increasing in India. Among major research efforts launched recently are a Centre for Climate Change sponsored by Ministry of Earth Sciences in the Indian Institute of Tropical Meteorology in Pune; and the proposed National Institute of Climate and Environment jointly sponsored by Ministry of Environment and Forests, and Indian Space Research Organization in Bangalore. The Gujarat State government has also announced its intention to set up a Department of Climate Change. In view of the plethora and complexities of climate-related problems facing various societal sectors and the paucity of major institutions working in this area, many more major efforts are required and I hope that ICCSIR will become an important and complementary component of a national network of institutions conducting research, education, and applications in climate and its societal impacts.

This report summarizes ICCSIR's progress in the first year; research papers based on work described in this report are in peer review or in preparation. ICCSIR's initial research projects are on analysis and modelling of heavy rainfall events in western India; interactions among air pollution, weather, and climate; and analysis and modelling of ocean-atmosphere interactions and their influence on the monsoon. ICCSIR has also started a project to educate college and university teachers and students about climate and its societal impacts. A B.Sc. (Environmental Science) course has been started jointly by ICCSIR and Government Science College in Ahmedabad with a full complement of 40 students. ICCSIR and CEPT University are planning to start M.Sc. and Ph.D. programmes in climate and its societal impacts from June 2010. Actual and forecast weather maps are made available to users via the ICCSIR Website, as is a quarterly newsletter *Climate for You*. To inform the public about climate and its impacts via the news media is also a major project of ICCSIR since its inception.

This progress would not have been possible without the tremendous support provided by ICCSIR's sponsors, the Excel Group and the Mamata Group, especially Shri Ashwin Shroff and Shri Mahendra Patel, respectively. ICCSIR would not have been born without their support and wise guidance. I gratefully acknowledge an initial research grant from Indian National Centre for Ocean Information Services, a centre of Ministry of Earth Sciences, Government of India; and a generous donation by the Shroff Family Charitable Trust. I also gratefully acknowledge the Scientific Advisory Committee's help in formulating ICCSIR's initial programmes.

I thank Shri Bipin Jha, Shri Devanshu Mehta, Shri Unmesh Mehta, Shri Pradip Mistry, Shri Janak Raval, Shri Kirit Shelat, Dr. Anupam Singh, Shri Mahendra Trivedi, Shri Deven Unakar, Shri Rathin Vaidya, Shri Dhiren Vaishnav, and Shri Mukund Vyas for their efforts in bringing ICCSIR to life and sustaining it. Shri Dhiren Vaishnav is also providing an invaluable service as ICCSIR's honorary administrative officer. ICCSIR also benefits immensely from very useful advice by Dr. J.N. Desai, a retired Professor of Physical Research Laboratory, Ahmedabad. I also thank the Ahmedabad Education Society and its Chairman Shri Shrenikbhai Kasturbhai for allowing us to make ICCSIR's initial home in one of the Society's buildings. Finally, I thank Drs. Deepak Vaidya and Satyendra Bhandari, and Shri Devanshu Mehta for their constructive review of an earlier version of this report.

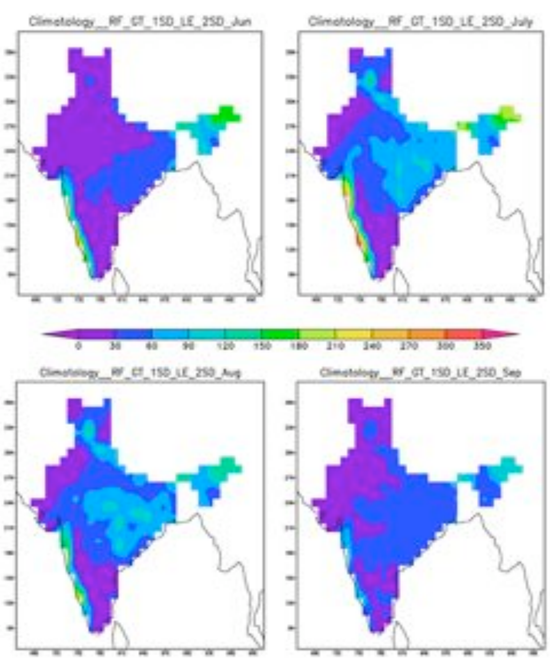
Vikram M. Mehta
Executive Director

Research

Heavy Rainfall Events in Western India

Heavy rainfall over river basins and urban areas, and resulting floods, pose major threats to human lives and living conditions, and cause severe economic impacts. There is an increasing perception that heavy rainfall events in western India are becoming more frequent and that the increased frequency may be related to climate change associated with increasing greenhouse gases. In this project, variability and long-term trends in rainfall events over western India are being analyzed.

Figure 1: Average rainfall anomalies (mm) in events between 1 and 2 standard deviations above the mean.



We are using daily, gridded rainfall data at 1° longitude – 1° latitude resolution over the entire country, based on 1803 raingauge stations, from 1951 to 2007. So far, we have analyzed only June, July, August, and September comprising the summer monsoon season in western India. Mean and standard deviation (SD) in rainfall were computed at each grid point for individual monsoon months for all 57 years. Then, time series of daily rainfall exceeding 1 SD (light events; RE1), 2 SDs (moderate events; RE2), and 3 SDs (heavy events; RE3) above the mean rainfall were prepared for each of the monsoon months. In order to quantify the degree of rainfall intensity in absolute terms, we also categorized rainfall events further in mm per day. It must be emphasized that even the lowest intensity event considered here (1SD) can be a high-impact event, specifically over a populated location.

The average variability of rainfall events during the 57 years' period is more over the rest of India for RE1 and RE2 events compared to western India (Figs.1 and 2).

The average variability of RE3 events is more in western India compared to other parts of India (Fig. 3). The % contribution of RE1, RE2, and RE3 events to the total monthly rainfall was also computed for western India. RE1 events contribute approximately 20% of the total monthly rainfall, with the maximum contribution in June and minimum in August. RE2 contributes approximately 15% to the total monthly rainfall, with the maximum contribution in June and minimum contribution in August. RE3 contributes 19% to 28% to the total monthly rainfall, with the maximum contribution in September and minimum in July. Out of the three categories of rainfall events, the total contribution is maximum from RE3 events and minimum from RE2 events. It is interesting to note that for July, RE1 events contribute maximum, compared to other months when the RE3 contribution to monthly rainfall is maximum.

Time series for each category of rainfall events over western India have been analyzed and subjected to trend analyses. Year-to-year variability as well as decadal timescale variability is observed in all monsoon months. RE1 shows a 95% statistically-significant decreasing trend in July, i.e. 5.6% per decade of the average RE1 for the period 1951-2007 over western India. RE2 events do not show any statistically significant trend over western India. RE3 events show a 99% statistically-significant increasing trend in June, i.e. 9.8% per decade of the average RE3 for the period 1951-2007 over western India and 95% statistically significant increasing trend in July, i.e. 4.3% per decade of the average RE3 for the period 1951-2007 over western India.

Figure 2: Average rainfall anomalies (mm) in events between 2 and 3 standard deviations above the mean.

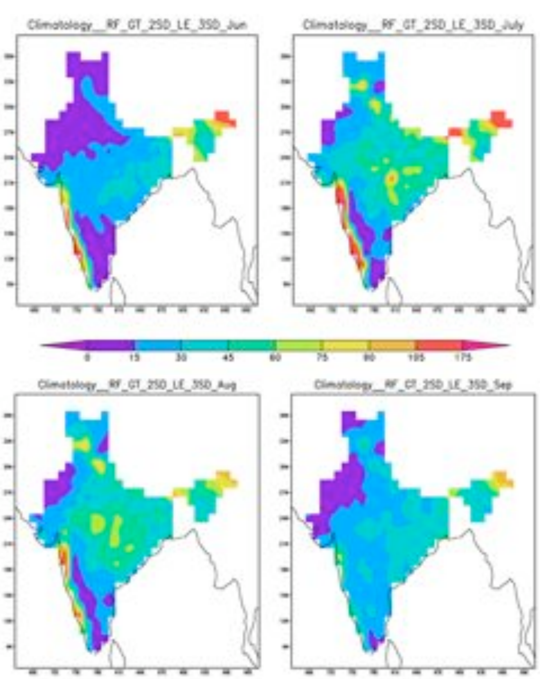
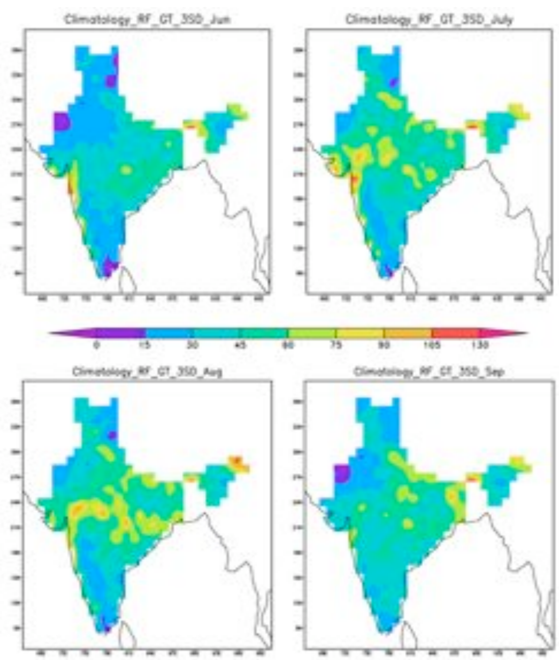


Figure 4 shows the year-to-year and longer timescale variability of RE1, RE2 and RE3 events over western India in June and July. The RE1 and RE2 contributions are increasing, but they are not statistically significant, whereas the RE3 contribution to the monthly rainfall is increasing and is statistically significant. On the other hand, RE1 and RE2 contributions are decreasing in July, whereas RE3 contribution is increasing and is statistically significant.

Figure 3: Average rainfall anomalies (mm) in events larger than 3 standard deviations above the mean.



These results show that rainfall in western India is highly variable on daily, monthly, annual, year-to-year, and longer timescales; and, therefore, it is almost impossible to assess if there are any linear or nonlinear trends attributable to greenhouse gas-induced climate change. These results also show that the estimated linear trends in RE1 and RE3 events are very small; while they are statistically significant, the trends are so small that it may not be possible to observe rainfall changes due to these trends in individual years.

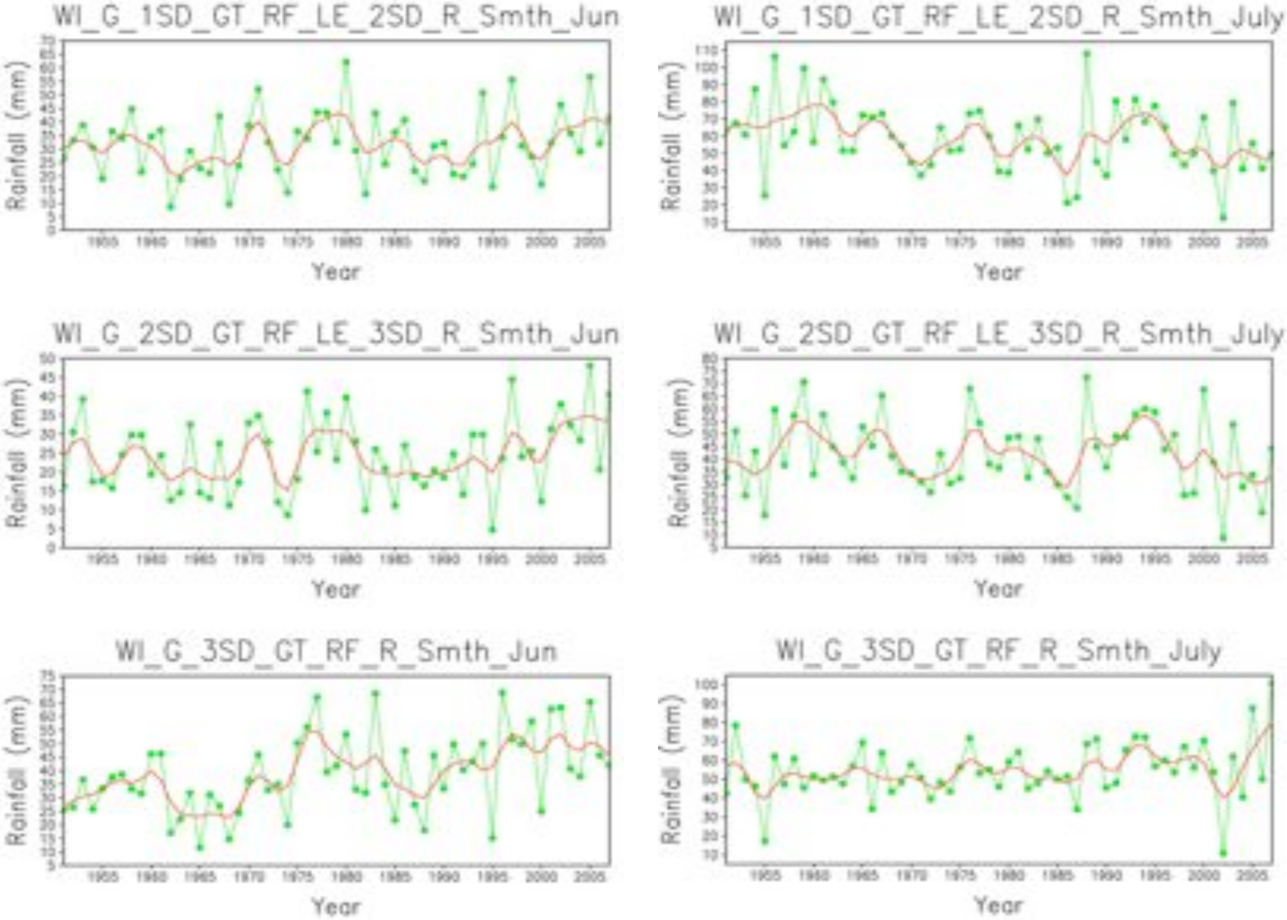


Figure 4: Time series of RE1, RE2, and RE3 events (green) in June (left column) and July (right column) over Western India (mm) and 9-point smoothed curve (red).

(Dhaval Prajapati)

Simulation of Heavy Rainfall Events over Western India with the Weather Research and Forecast (WRF) Model

Western India has a long history of suffering from floods and water-logging disasters. With rapid developments of society and economy, losses due to these factors become increasingly important and pose a major constrain on further development. Therefore, one of the primary research areas in ICCSIR is to understand atmospheric processes that result in heavy rainfall, causing destructive floods in major river basins and urban areas in western India, and subsequently develop experimental prediction systems for such heavy rain events. We use the state-of-the-art numerical Weather Research and Forecast (WRF) model to simulate these events with the goals of understanding physical processes causing these events, to assess accuracy of the simulations, and to assess predictability of such events.

The WRF model is a state-of-the-art forecast model and data assimilation system that has advanced both the understanding and prediction of weather. It is suitable for predicting weather at scales ranging from several hundred meters to thousands of kilometers, ideal for understanding multi-scale interactions of physical processes that result in very heavy rainfall. This model has been developed by a number of weather and climate research institutions based in the United States (see http://www.wrf-model.org for details) and has been successfully used for high resolution weather simulations and predictions. At ICCSIR, we have developed computational and analysis infrastructure to conduct high-resolution WRF simulations. We have simulated a number of heavy rain events, including those that devastated Mumbai (26 July 2005), Ahmedabad (8 august 2005), and Surat (6 August 2006). We are currently making multiple simulations of these events to test WRF model performance with various possible model configurations and physical parameterizations. A detailed analysis of these simulations will help select optimum model configuration for western India and help develop insight into atmospheric processes that result into heavy rainfall events.

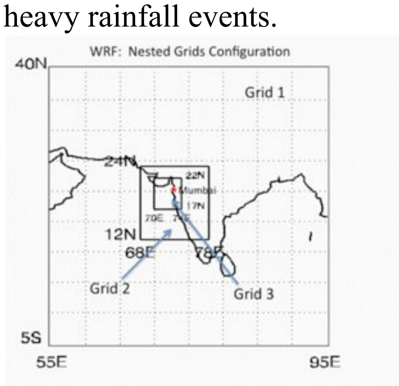
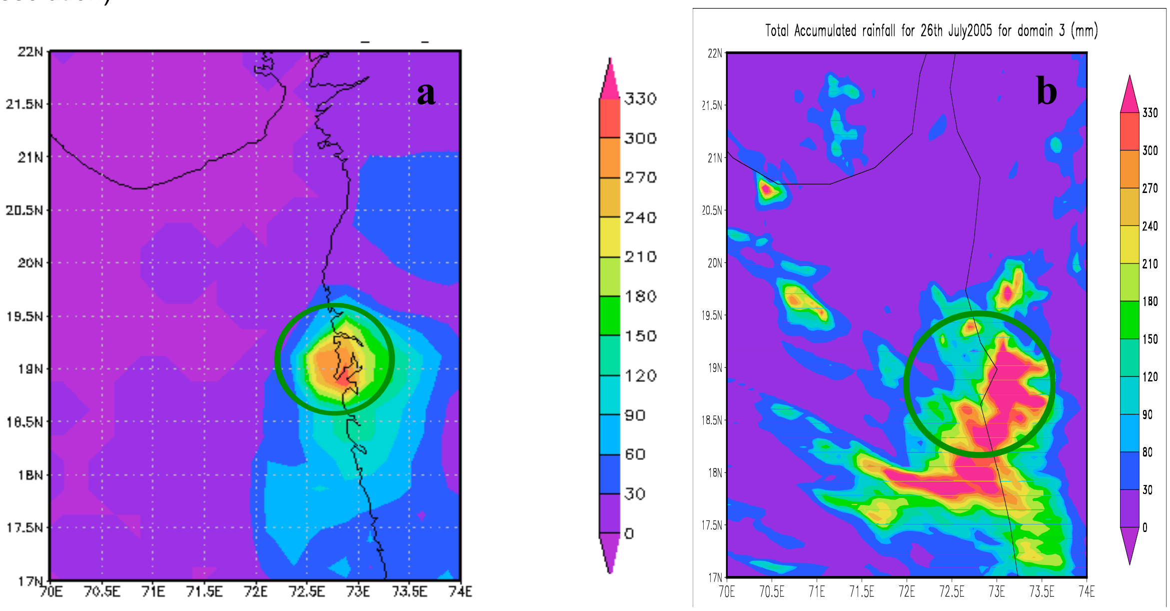


Figure 1: Configuration of three nested grids.

Figure 1 shows an example of a WRF configuration with three nested grids. This particular WRF configuration is used to simulate the 26th July, 2005 heavy rain event over Mumbai in which the outer grid domain resolution is set to 45 km, the middle grid domain resolution to 15 km, and the inner-most grid resolution is set to 5 km. Within all the grids, land surface properties are specified at 10m resolution. The WRF simulations are carried out with one-way nesting (information is communicated only from successive outer to inner grid) and also with two-way (bi-directional information exchange among all three grids) nesting. In addition, several simulations are conducted with different parameterizations of atmospheric convection (moisture and heat transport from surface and lower atmosphere to above) and microphysics (formation, growth, fall-out, and decay of cloud, rain, snow, ice particles) processes. Typically, in our simulations of rain events we use initial and boundary conditions provided from the National Center for Environmental Prediction (NCEP) Final global analysis (FNL). We run the model on eight processors of the Dell Precision T3400 Intel Core 2 Quad machine. In case of one way nesting a typical 48-hour simulation takes approximately 20 min for Domain 1, 1hs 20 min for Domain 2 and 7hrs 28 min for Domain 3 run. For two way nesting time taken to complete the entire three Domains run is approximately 26 hours of wall-clock time.

Here we present preliminary results of our one-way nesting simulation of the Mumbai rain event. Figure 2a shows rainfall distribution with 0.25°x0.25° (approximately 25x25 km^2) resolution observed from NASA's Tropical Rainfall Measurement Mission

Figure 2: Accumulated rainfall (mm) over 24 hours from 5:30 AM 26 July 2006. (a) Satellite observed (TRMM 3B42; 25 km x 25 km resolution), and (b) WRF model Domain 3 (5 km x 5 km resolution).



(TRMM) on 26th July 2005. Figure 2b shows the WRF simulation of rainfall accumulated over the 24-hour period between 00 UTC of 26th July and 00 UTC of 27th July 2005 for the inner-most grid domain shown in Figure 1 with 5x5 km^2 resolution. It is evident from Figures 2a and 2b that the WRF simulation is in a reasonable agreement with the observed rainfall. Centers of very heavy rainfall over Mumbai are evident in both figures. Moreover, it is encouraging to note that over Mumbai the WRF-simulated, accumulated rainfall on July 26th (259 mm), agrees well with that measured by the India Meteorological Department (IMD) (255 mm). Note that the model simulation in Figure 2b has a much higher resolution than the TRMM rainfall shown in Figure 2a. Therefore, a more detailed structure of rainfall is visible in the model simulation, particularly over the Western Ghats. Figure 3 shows time series of 3-hourly rainfall from the WRF (time and date 6 hours to 48 hour simulation) at 18°58 North, 72°49 East.

We plan to continue to conduct simulation experiments with the WRF model to assess rainfall predictability over western India. We are also in the

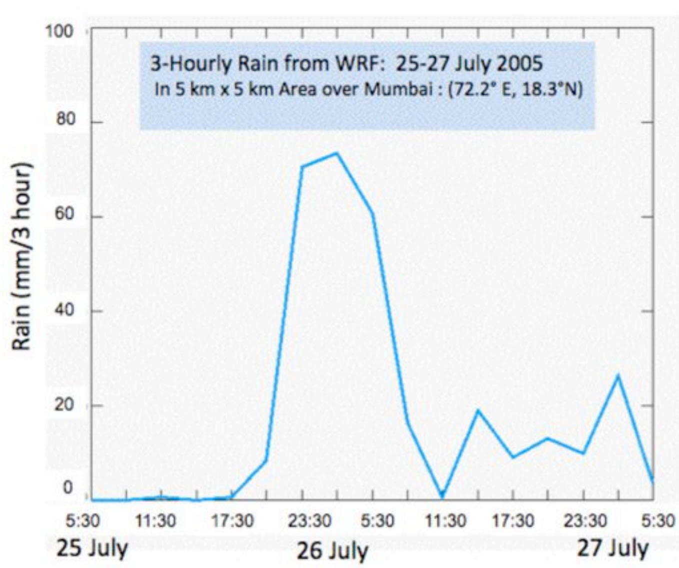


Figure 3: WRF-simulated, 3-hourly rain in 5 km x 5 km area over Mumbai from 5:30 AM (IST), 25 July 2005 to 5:30 AM (IST), 27 July 2005.

process of including an atmospheric chemistry module in the WRF model to test how various types of anthropogenic aerosols may influence rain intensity and distribution over major urban and industrial areas.

(Bakshi H. Vaid and Amita V. Mehta)

Interactions among Air Pollution, Weather, and Climate in Western India

Urban air pollution is rapidly becoming an environmental problem of public concern worldwide. It can influence public health and local/regional weather and climate. We are conducting a study of air pollution and its interactions with weather and climate in the Ahmedabad mega city (human population over 5 million) region in Gujarat State. The city is in a semi-arid region on the banks of the Sabarmati River in north-central Gujarat. It spans an area of 205 sq. km (79.15 square miles). In the present study, airborne particulate pollutants data were collected for a period of 4 years (2005-2008) at 13 locations in Ahmedabad by the Gujarat Pollution Control Board with Respirable Dust Samplers (RDSs).

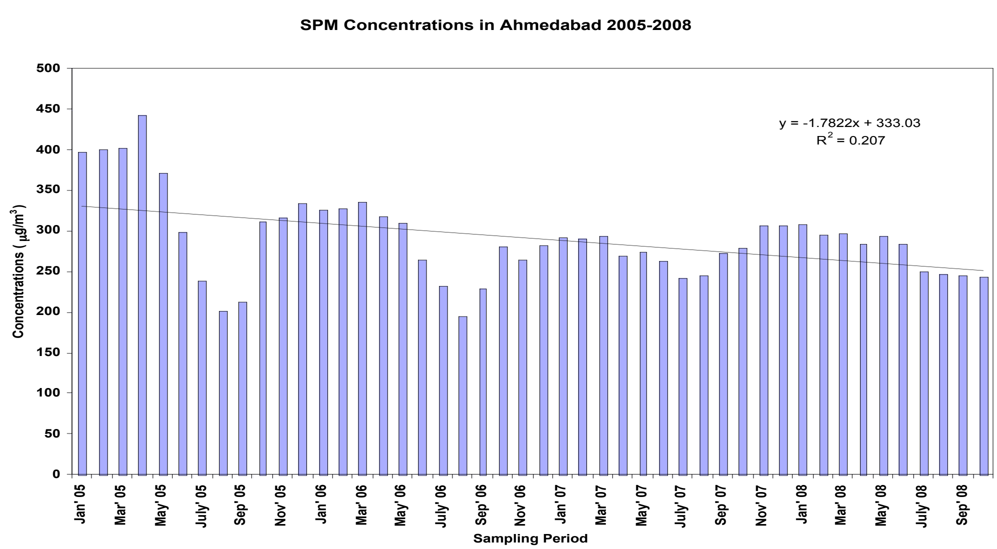


Figure 1 (a): SPM concentration in Ahmedabad 2005-2008

The observed Suspended Particulate Matter (SPM) concentrations varied from 66.0 to 786.0 g/m^3, (annual permissible limit is 70 to 360 g/m^3) and concentrations of Particulate Matter of aerodynamic diameters less than 10 microns (PM_{10}) ranged between 17.0 and 327.0 g/m^3 (annual permissible limit is 50 to 120 g/m^3). The seasonal- and annual-average concentrations of the two pollutants were mostly above Indian air quality standards and were generally comparable with those observed in most other Indian urban areas. During this study period, there was a continuous decrease of particulate pollutants concentrations within Ahmedabad (Figures 1a and 1b); however, the concentrations were just above the permissible limits set by the Central Pollution Control Board (CPCB). The observed particulate pollutants concentrations were compared with meteorological variables such as rainfall, temperature, and wind speed. Both SPM and PM_{10} showed significant negative correlations with rainfall, implying that the pollutants are washed out of the atmosphere by rain.

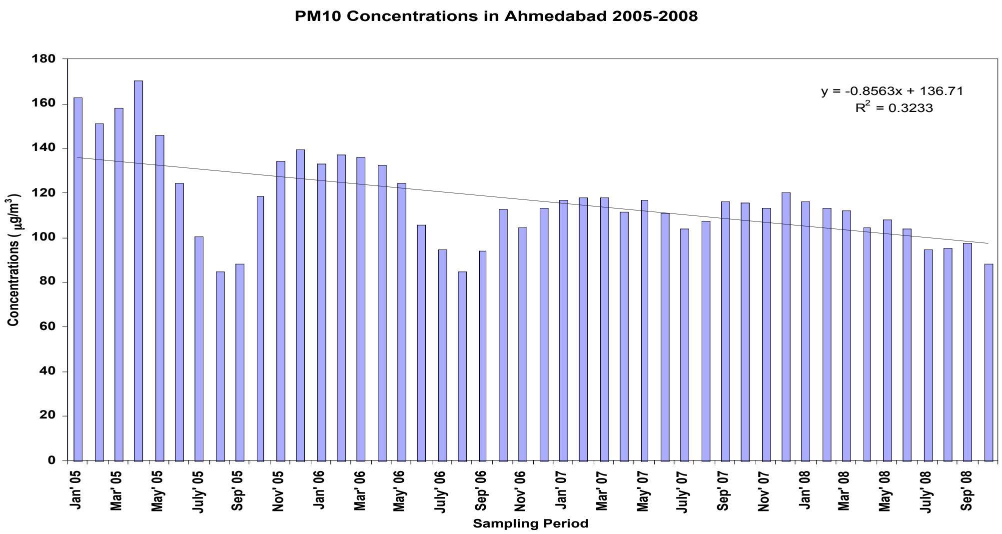


Figure 1 (b): P M_{10} concentrations in Ahmedabad 2005-2008

An Air Quality Index (AQI), as defined by the United States Environmental Protection Agency and CPCB, was calculated for all stations for all months. AQI values varied from 25 to 193.3. AQI was high in summer and low in monsoon. AQI values varied from Good (0-50) to Hazardous (300-500). On the basis of the AQI values, it is found that the atmospheric environment of Ahmedabad is highly polluted above permissible standards. From these AQI estimates, it is amply clear that the two particulate pollutants are emerging as critical pollutants for urgent attention because they are degrading air quality in Ahmadabad with consequent effects on public health. This indicates an urgent need for a systematic control of atmospheric pollutants from anthropogenic sources, especially particulate pollutants, to safeguard the human population, flora, and fauna as well as social assets such as cultural sites in the mega-city.

During the past decade, there have been significant advances in satellite remote sensing of air pollution with the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite. MODIS provides a daily morning and afternoon, global coverage. MODIS's estimates of Aerosol Optical Depth (AOD) provide a unique opportunity to impute daily, worldwide estimates of air quality. Daily average AOD estimates derived from the MODIS level 3 gridded data at 1° longitude – 1° latitude resolution are used in our study. Annual-average AOD values varied from 0.24 to 0.39 in Ahmadabad between 2001 and 2008. Figure 2 shows the time series of AOD over Ahmedabad. AOD is increasing in Ahmedabad for last several years. It was also noticed that mean values of AOD were high in monsoon months of June and July. The mean AOD value then decreased to reach a minimum in winter. During, June and July, when the southwest monsoon is active over most of India, MODIS overestimates the AOD. It should be noted that during the monsoon months, the sky is cloudy and AOD retrievals could be affected by the cloud cover. Cloud cover restricts the number of days of AOD retrievals during this period. This could be one of the reasons for high AODs in monsoon season.

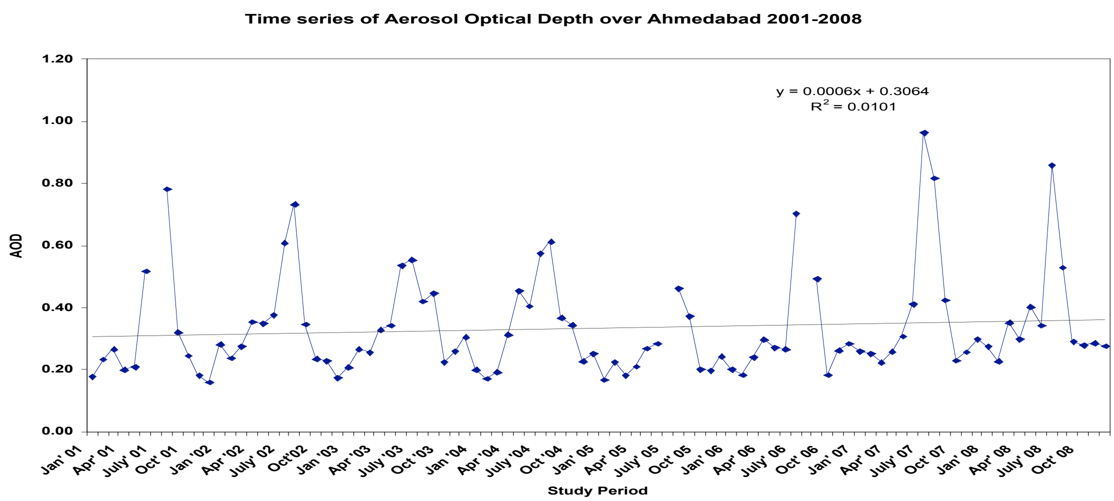


Figure 2: Monthly variations of AOD over Ahmedabad during 2001-2008.

The AOD data were compared with urban particulate pollutants and rainfall data. It was noted that AOD, and SPM, and PM_{10} are negatively correlated with rainfall. From this study, it was noted that while AOD is increasing over Ahmedabad, SPM and PM_{10} concentrations are decreasing over Ahmedabad. High population density locations are also large aerosol sources due to fossil fuel consumption, and wood and other fuels used for cooking purpose which contribute in a significant way to higher AOD levels in cities such as Ahmedabad.

We are extending this study over urban and rural areas of western India.

(B. Vijay Bhaskar)

Analyses of Atmospheric Freshwater Flux in the Arabian Sea-Bay of Bengal-Indian Ocean Region and its association with IOD, ENSO, and the Indian Monsoon Variability

The Arabian Sea-Bay of Bengal-Indian Ocean region plays a very important role in the Indian monsoon and global climate variability. The ocean's influence in the climate system is mainly via air-sea sensible and latent heat, momentum, and freshwater fluxes. Observations and model simulations suggest that net freshwater input into the oceans may be as important as surface heat flux in contributing to the buoyancy of the upper oceans at seasonal and longer timescales. Therefore, it is very important to study net fresh water flux variations. There are three types of net freshwater input to the oceans: net atmospheric freshwater (evaporation E minus precipitation P; EmP), melting sea-ice, and river runoff. Changes in these net freshwater inputs to the oceans can change salinity and, therefore, density of seawater. Changes in density, in turn, can change ocean circulations that can eventually change heat transport and temperature.

In the present study, observed EmP variations associated with the Indian Ocean Dipole (IOD), El Niño-Southern Oscillation (ENSO), and the Indian monsoon rainfall using OAflux evaporation and GPCP precipitation data sets for 1979-2006 have been analysed. In order to investigate EmP variations, anomalies were computed by subtracting the 28 years long-term mean from the total EmP fields. Composite analyses were then carried out to quantify EmP variations during positive and negative IOD events; above- and below-average all-India monsoon rainfall; and El Niño and La Niña events. September-October-November (SON) of all positive and negative IOD events, June-July-August-September (JJAS) of all above- and below-average all-India monsoon rainfall years, and December-January-February (DJF) of all El Niño and La Niña events during 1979 to 2006 were included in the composite analyses.

Composite maps of EmP anomalies during positive and negative IOD events, above- and below-average all-India rainfall, and El Niño and La Niña events are shown in Figure 1. Positive IOD years chosen in the study were 1982, 1994, 1997, 2006; negative IOD years were 1989, 1992, 1996, 1998; above-average monsoon years were 1987, 2002 and 2004; below-average monsoon years were 1987, 2002 and 2004; El Niño years were 1982, 1991, 1994 and 1997; and La Niña years were 1988, 1998 and 2000. As Figure 1 shows, significant interannual variability is observed in EmP during the IOD, ENSO, and above- and below-average all-India rainfall years.

A dipole-like pattern is observed in EmP anomalies over the eastern and western tropical Indian Ocean during the positive and negative IOD events (Figure 1). Strong positive EmP (evaporation dominating precipitation) anomalies appeared in eastern equatorial Indian Ocean (90º-110ºE, 10ºS-equator) and strong negative EmP (precipitation dominating evaporation) anomalies appeared in the western equatorial Indian ocean (50º-70ºE, 10ºS-10ºN). During negative IOD years, large, negative EmP anomalies appeared in the eastern equatorial Indian Ocean (90º-110ºE, 10ºS-equator) and small, positive EmP anomalies appeared in the western equatorial Indian Ocean (50º-70ºE, 10ºS-10ºN).

During JJAS in above-average monsoon rainfall years, negative EmP (precipitation more than evaporation) anomalies appeared in the Bay of Bengal-Arabian Sea-equatorial Indian Ocean region, except in the eastern equatorial Indian Ocean. During below-average monsoon rainfall years, positive anomalies appeared in the Bay of Bengal and the eastern Arabian Sea, and negative anomalies appeared near the Inter-Tropical Convergence Zone (ITCZ) and in the western Arabian Sea.

Composite analysis results for El Niño and La Niña also showed the dominance of interannual variability. During DJF months of El Niño years, negative anomalies appeared in the entire Indian Ocean including the Bay of Bengal, the Arabian Sea and the

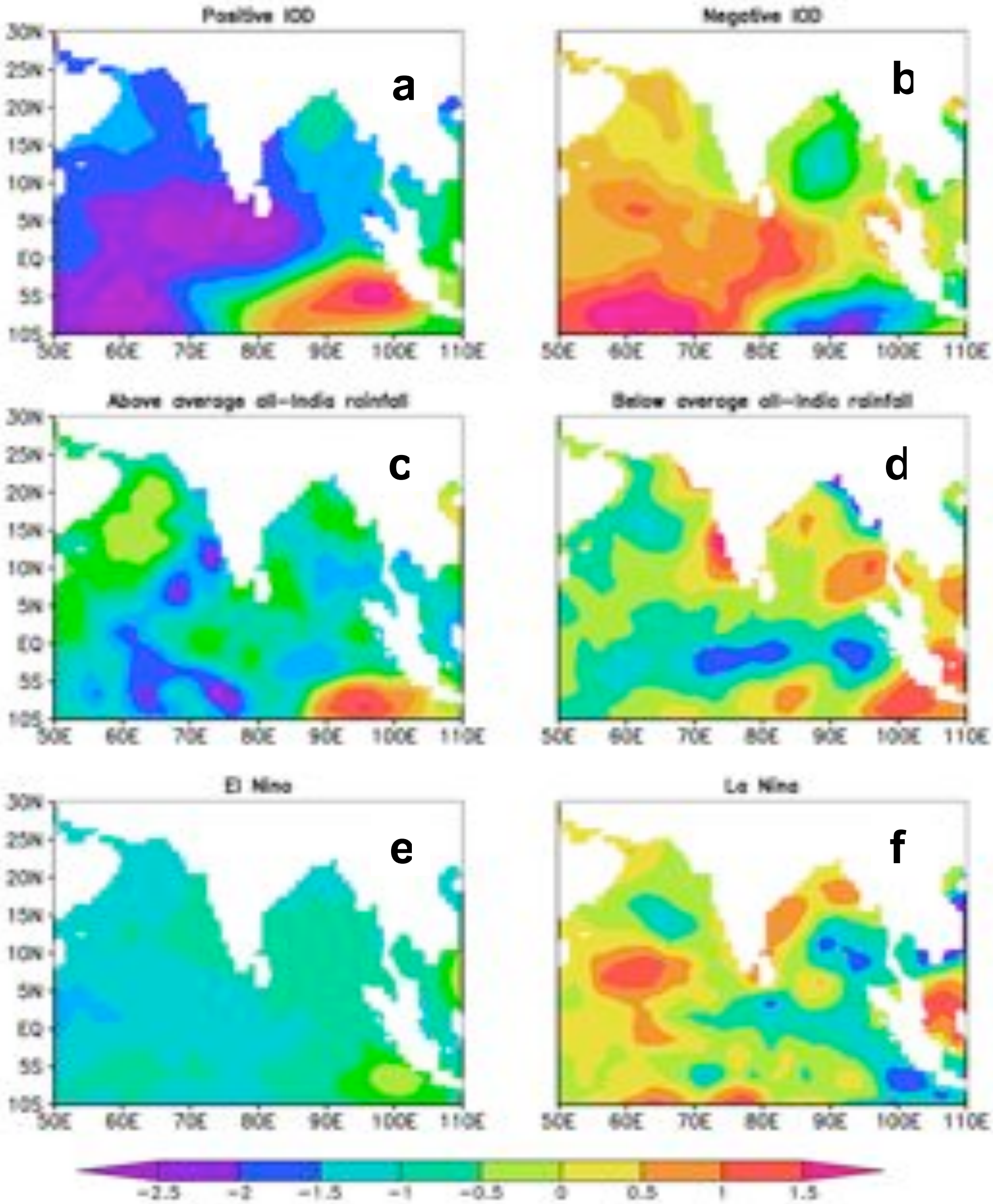


Figure 1: Composite maps of EmP anomalies (mm/day) for SON months of (a) positive (1982, 1994, 1997 and 2006), and (b) negative (1989, 1992, 1996, 1998 and 2005) IOD events; JJAS months of (c) above-average (1988 and 2003), and (d) below-average (1987, 2002 and 2004) all-India monsoon rainfall; and DJF months of (e) El Niño (1982, 1991, 1994 and 1997), and (f) La Niña (1988, 1998 and 2000) events.

equatorial Indian Ocean except in the eastern equatorial Indian Ocean. During La Niña years, positive EmP (precipitation less than evaporation) anomalies appeared in the western Bay of Bengal and the central Arabian Sea, and negative anomalies appear in the eastern Bay of Bengal and the eastern equatorial Indian Ocean.

The results in this project so far are suggestive rather than definitive because of the relatively small number of IOD, ENSO, and Indian monsoon events. Future work in this project will include analyses of salinity measurements made by the ARGO and other programs; and experiments with the NCAR CCSM3 global coupled model to study potential impacts of EmP anomalies in ocean and climate variability, especially in IOD, monsoon, and ENSO variability.

(Anuradha Modi)

Education

A one-day workshop on climate and its societal impacts was organized at ICCSIR on August 9, 2008. Approximately 35 teachers and students from five universities in Gujarat participated in the workshop. Scientists from ICCSIR, Space Applications Centre, Physical Research Laboratory, and Anand Agricultural University constituted the faculty of the workshop. We are planning to organize a one-week workshop for college and university teachers in January 2010.

ICCSIR signed a Memorandum of Understanding (MOU) with the Government Science College, K.K. Shastry Campus, Khokhara, Ahmedabad to launch a new B.Sc. (Environmental Science) course and a Post-Graduate Diploma in Climate Technology. ICCSIR scientists are helping in developing the curricula and teaching many of the subjects in the B.Sc. course. The course students will be able to carry out required project work in ICCSIR under the guidance of ICCSIR's scientists. The B.Sc. course started in June 2009. We plan to start the Post-Graduate Diploma in Climate Technology from June 2010.

ICCSIR also signed an MOU with CEPT University in Ahmedabad to establish joint research and education programmes, including a Ph.D. programme, on climate and its impacts on water resources, agriculture, urban and rural economies, public health, and other sectors. Two post-graduate students from CEPT University are working on projects in ICCSIR on applications of Geographic Information System (GIS) in hydrometeorology and climatology, and applications of GIS to study air pollution over Ahmedabad.

An ICCSIR Research Fellow, Ms. Anuradha Modi, was selected to participate in the 4th International Summer School in Corsica, France from 3rd to 15th August.

We have started a seminar series. Details are given in the following Table.

Speaker	Affiliation	Date	Title
Dr. V. M. Mehta	ICCSIR	15 Nov. 2008	Decadal Variability of the Indo-Pacific Warm Pool and Its Association with Atmospheric and Oceanic Variability in the NCEP–NCAR and SODA Reanalysis
Dr. J.N. Desai	Physical Research Laboratory	19 Dec. 2008	Light Scattering: Applications to Aerosols
Dr. R. Ramesh	Physical Research Laboratory	30 Jan. 2009	Deciphering Past Monsoon Variations from Tree-rings and Speleothems
Dr. S. Ramachandran	Physical Research Laboratory	27 Mar. 2009	Regional and Seasonal Variations in Aerosol Optical Characteristics over India: Radiative Impacts
Dr. S. Bhandari	ICCSIR	28 Apr. 2009	Radar Altimetry from Space: an Alternative Means of Looking at Rainfall over Global Oceans
Dr. B.H. Vaid	ICCSIR	27 Nov. 2009	Numerical Simulations of the 26 July 2005 Heavy Rainfall Event over Mumbai using the Weather Research and Forecast (WRF) Model

(Deepak B. Vaidya)

Outreach

Quarterly Newsletter: *Climate for You*

ICCSIR aims to communicate effectively and regularly with non-specialists and specialists in climate and its societal impacts, therefore a quarterly newsletter *Climate for You* was started. The first issue of *Climate for You* was published in October 2008, containing articles on goals and aspirations of ICCSIR to address the unique problems of weather and climate variability and changes in western India; research to nowcast weather over western India; challenges in climate research and predictions; ICCSIR's education programme; and teachers' workshop. Subsequent issues have contained articles on topics such as reconstruction of past climate, its connection with the current one, and the requirement of more data for future prediction; climate variability in Antarctica; decadal climate variability; drought monitoring and early warning system in western India; an interactive forum on climate change and its impacts; high-resolution rain simulations over western India; natural decadal climate variability phenomena; and an evolving international effort on decadal variability and predictability/prediction. The most recent issue (Sept. 2009) of *Climate for You* also contains a discussion of possible impacts of the ongoing El Niño event on the 2009 Indian monsoon, and a description of daily weather forecasts and observed rainfall available from ICCSIR's Website. *Climate for You* is available free of charge and is distributed to hundreds of readers all over the world via e-mail and printed copies. Current and past issues are also available from www.iccsir.org.

(Bakshi H. Vaid)

Weather and Climate Information on the ICCSIR Website

Outreach and dissemination of weather and climate information over India are important components of ICCSIR's objectives in addition to scientific research and educational activities. A major step along this direction is to establish an information portal on the ICCSIR web site where maps of total monsoon rainfall (June to September) obtained from NASA's Tropical Rainfall Measuring Mission (TRMM) multi-satellite algorithm 3B42 can be viewed for years 1998 to 2008 (http://www.iccsir.org/junetoseptrainfall.html). The rainfall product is obtained from NASA-Goddrad Earth Science Data and described on Information Service Center (http://mirador.gsfc.nasa.gov/cgi/bin/mirador/presentNavigation.pl?tree=project&project=TRMM). This data product is based on a combination of passive microwave radiances from TRMM, and microwave-calibrated infrared radiances from geostationary and low Earth-orbit satellites. The spatial resolution of this rainfall product is 25 km x 25 km. These rainfall maps help identify general areas of heavy, moderate, and low rainfall over the Indian region.

Additionally, a close inspection of these rainfall maps also show year-to-year differences in rainfall.

Beginning May 2009, ICCSIR also began to provide near-real time, daily rainfall maps from TRMM product 3B42 (http://www.iccsir.org/dailyrainfall.html) with 25 km x 25 km resolution. While there is one-to-two day latency in receiving the TRMM 3B42 data, the daily maps have been very useful in monitoring monsoon progression during 2009. For example, Figure 1 shows rainfall on 28 August 2009, when substantial rainfall occurred over Gujarat after a long dry spell.

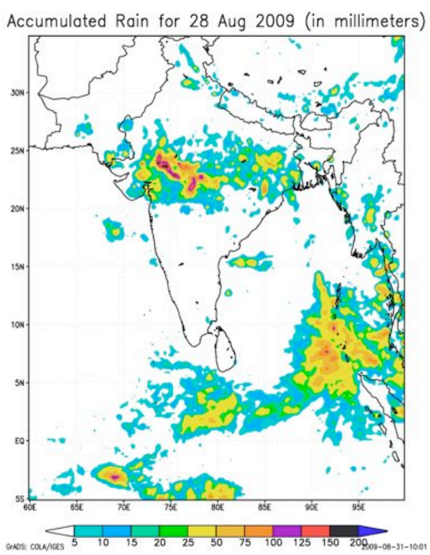


Figure 1: Accumulated, 24-hours Rainfall (mm) from TRMM 3B42 for 28 August 2009.

Another important service that ICCSIR started in May 2009 was to provide 24- and 48-hour forecast maps of rainfall and surface air temperature based on operational Global Forecast System (GFS), from the National Center for Environmental Predictions (NCEP), USA (http://www.iccsir.org/dailyweatherforecast.html). The forecast is currently available at 1°x1° latitude-longitude (approximately 100 km x 100 km) grid spacing. An advance warning of likely arrival of rain system or heat/cold wave can be obtained up to two days in advance from these forecast maps. This facility can be very useful for farmers for whom timing of rainfall is extremely important at various stages of the crop cycle. Furthermore, during heavy rainfall events, the rainfall maps can be utilized to identify general areas of flooding in advance. Also, this forecast can be useful to general public for planning outdoor activities and travel.

These web-based information portals are being developed further to provide climate information, including rainfall maps, specifically for western India and for Gujarat State. In addition, as described earlier in this report, a high-resolution (4 km x 4 km) weather forecast model is currently being tested in ICCSIR, which will eventually be used to provide 3-hourly forecasts of rain, winds, temperatures, and humidity over various parts of western India via the ICCSIR Website.

(Amita V. Mehta)

Lectures in Colleges, Universities, and Research Laboratories

As a component of our outreach activities, ICCSIR scientists give lectures in colleges, universities, and research laboratories about climate variability, potential climate changes, and their societal impacts. The lectures delivered since ICCSIR's inception are listed in the following Table.

Speaker	Place	Date	Title
Vikram Mehta	Physical Research Laboratory, Ahmedabad	5 March 2009	Possible Influences of Atmospheric and Riverine Fresh Water on Ocean Circulations, Temperatures, and Climate
Vikram Mehta	Department of Botany, Gujarat University, Ahmedabad	25 Feb. 2009	An Introduction to Climate: Physics of Variability and Changes
Amita Mehta	Govt. Science College – KKS Campus, Ahmedabad	7 August 2009	An Introduction to Climate: Physics of Variability and Changes
Vikram Mehta	Govt. Science College – KKS Campus, Ahmedabad	7 August 2009	An Introduction to Climate: Physics of Variability and Changes
Bakshi H. Vaid	Department of Geography, Gujarat University, Ahmedabad	28 August 2009	An Introduction to Climate: Physics of Variability and Changes

(Bakshi H. Vaid)

Interactions with News Media

ICCSIR considers it a very important responsibility to interact with news media to provide state-of-the-science information to the public about weather and climate variability and changes, and their societal impacts. Dr. Vikram M. Mehta, Director, ICCSIR, initiated the media coverage by his interview to DNA news paper in November 2008. Since then, many interviews have been given by ICCSIR scientists to English and Gujarati news papers such as Western Times, Gandhinagar Samachar, Jai Hind, Divya Gujarat, Prabhat, Gujarat Praman, Nirmal Gujarat, and Gujarat Today on topics such as climate change, impacts of the ongoing El Niño event on the monsoon, and availability of weather forecasts from the ICCSIR Website.

(Bakshi H. Vaid)

The ICCSIR Family

Name	Education	Area(s) of Expertise	Designation	e-mail Address
Satyendra M. Bhandari	M. Sc. (Physics/Electronics), Univ. of Jodhpur, 1968; Ph.D. (Space Physics/Radio Astronomy), Physical Research Laboratory and Tata Institute of Fundamental Research, 1978	Remote sensing, atmospheric and oceanic physics, Antarctic and Arctic research, programme management	Senior Visiting Scientist	satyendra.bhandari @iccsir.org
Vikram M. Mehta	M. Sc. (Physics), Gujarat Univ., 1977; P. G. Diploma in Space Science & Their Applications, Gujarat Univ., 1978; P. G. Diploma in Physics, Univ. of Saskatchewan, Canada, 1984; M.S. (Meteorology), Florida State Univ., U.S.A., 1986; Ph.D. (Meteorology), Florida State Univ., U.S.A., 1990	Decadal climate and ocean variability and predictability; climate impacts on water resources, agriculture, and public health	Executive Director; Adjunct Professor, CEPT University; also, Executive Director, Center for Research on the Changing Earth System, U.S.A.	vikram.mehta @iccsir.org
Amita V. Mehta	M. Sc. (Physics), Gujarat Univ., 1980; P. G. Diploma in Physics, Univ. of Saskatchewan, Canada, 1984; M.S. (Meteorology), Florida State Univ., U.S.A., 1987; Ph.D. (Meteorology), Florida State Univ., U.S.A., 1991	Infrared and microwave remote sensing, mesoscale atmospheric modeling, university education	Research Advisor, ICCSIR; also, Research Assistant Professor, Univ. of Maryland-Baltimore County; and Research Scientist, NASA-Goddard Space Flight Center	amita.mehta @iccsir.org
Anuradha Modi	M. Tech. (Atmos. Sci.), Andhra Univ., 2007	Ocean-atmosphere interactions	Senior Research Fellow	anuradha.modi @iccsir.org
Dhaval Prajapati	M. Sc. (Nuclear Sci.), M.S. Univ., 2003	Climate analysis	Senior Research Fellow	dhaval.prajapati @iccsir.org

Bakshi H. Vaid	M. Sc. (Physics), HNB Grahwal Univ., 2001; B. Ed., Jammu Univ., 2003; M. Tech. (Atmos. Sci.) Pune Univ., 2004; Ph. D. (Atmos. and Space Sci.) Pune Univ., 2008	Tropical oceanography; mesoscale atmospheric modeling; outreach	Assistant Professor	bakshi.vaid @iccsir.org
Deepak B. Vaidya	M.Sc.(Physics), Gujarat Univ., 1964; Ph.D. (Physics), Gujarat Univ., 1976	Light scattering and its applications in astrophysics and atmospheric science; college and university education	Education Advisor	deepak.vaidya @iccsir.org
B. Vijay Bhaskar	M.Sc., Energy Science - Madurai Kamaraj Univ.; Ph.D., Energy Science (Atmospheric Particulate Pollutants Study), Madurai Kamaraj Univ., 2008	Observation and modelling of air pollution-climate interactions	Assistant Professor	vijay.bhaskar @iccsir.org
Yashesh Vyas	M.B.A. (Finance)	Accounting and office management	Office Manager	yashesh.vyas @iccsir.org

(Yashesh Vyas)

ICCSIR building in the Ahmedabad Education Society campus

Everyone is looking towards ICCSIR for climate information in western India!