

**INDIAN CENTRE FOR CLIMATE AND
SOCIETAL IMPACTS RESEARCH (ICCSIR)**

Annual Report 2015 - 2016



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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.

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Contents

1	Research Activities	4
1.1	Decadal Climate variability and its impact on Southwest Indian monsoon	5
1.2	Trends in Aerosol optical properties over South Asia	7
1.3	Physical and dynamical parameterization	9
1.4	Vegetation carbon storage in Rukmavati River Basin	10
1.5	Role of El Niño on Southwest Monsoon of Gujarat	12
2	Application and outreach activities	14
2.1	ICCSIR's weekly weather forecast bulletin	14
2.2	Dissemination of current weather data	14
2.3	Dissemination of Long Range Weather forecast	15
2.4	Satellite imagery	15
2.5	Training Programme	15
3	Educational activities	16
4	Research Publication and participation in conferences	17
5	Summary and Future plan	19
5.1	Summary	19
5.2	Future Plan	20

Chapter 1

Research Activities

This part of report contains the scientific research activities carried out from April, 2015 to March 2016. Presently, ICCSIR is involved in two scientific projects details given below :

- Project title : “South Asian Precipitation: A Seamless Assessment: SAPRISE”
Funding agency : Ministry of Earth Sciences, Govt. of India under the Indo-UK Changing Water Cycle Programme
- Project title : “Investigation of the role of black carbon on aerosol radiative forcing over western India”
Funding agency : Department of Science and Technology (DST), Govt. of India.
- Project title : “Use of GIS in Rukmavati River Basin for sustainable agriculture”,
Funding Agency : Shroff Family Charitable Trust (SFCT), Mumbai.

1.1 Decadal Climate variability and its impact on Southwest Indian monsoon

Rohit Srivastava, Satyendra Bhandari and Vikram Mehta

The southwest or Indian summer (June to September) monsoon provides about 80% of annual rainfall. Variations in its timing, intensity and duration have a dramatic impact on society. Empirical studies suggest that the decadal climate variability (*e.g.*, Pacific Decadal Oscillation (PDO) is associated with southwest Indian monsoon rainfall variability. Effects of these decadal-multidecadal climate variability phenomena can manifest themselves on the southwest Indian monsoon via their modulation of Walker and Hadley Circulations, and atmospheric Rossby waves. It is very important to ensure that monsoon prediction models represent and predict these phenomena and their influences on the monsoon accurately.

The Earth System Models (EaSMs) skill, however, varies by averaging region and decade. It was also found that volcanic eruptions influence SSTs and are one of the sources of decadal SST hindcast skill. In the actual climate system, however, volcanic eruptions themselves are not predictable, and therefore, their effects on the climate system can only be predicted after eruptions. The study of long term trends in the characteristics of the within-season temporal profile of southwest monsoon rainfall over western India during the last five decades in relation to decadal climate variability suggested no significant long-term trends have been observed in this study. Slow decadal scale variations observed are analysed in relation to Pacific Decadal Oscillations (PDO). Daily variations in rainfall anomaly show opposite characteristics during negative and positive phases of PDO. The above-normal rainfall (>25%) is found during the starting phase of monsoon in negative PDO (Figure 1.1). The outcome of the study will be useful in improving the predictability of decadal climate variability in Global Earth System Models and their influences on southwest Indian Monsoon.

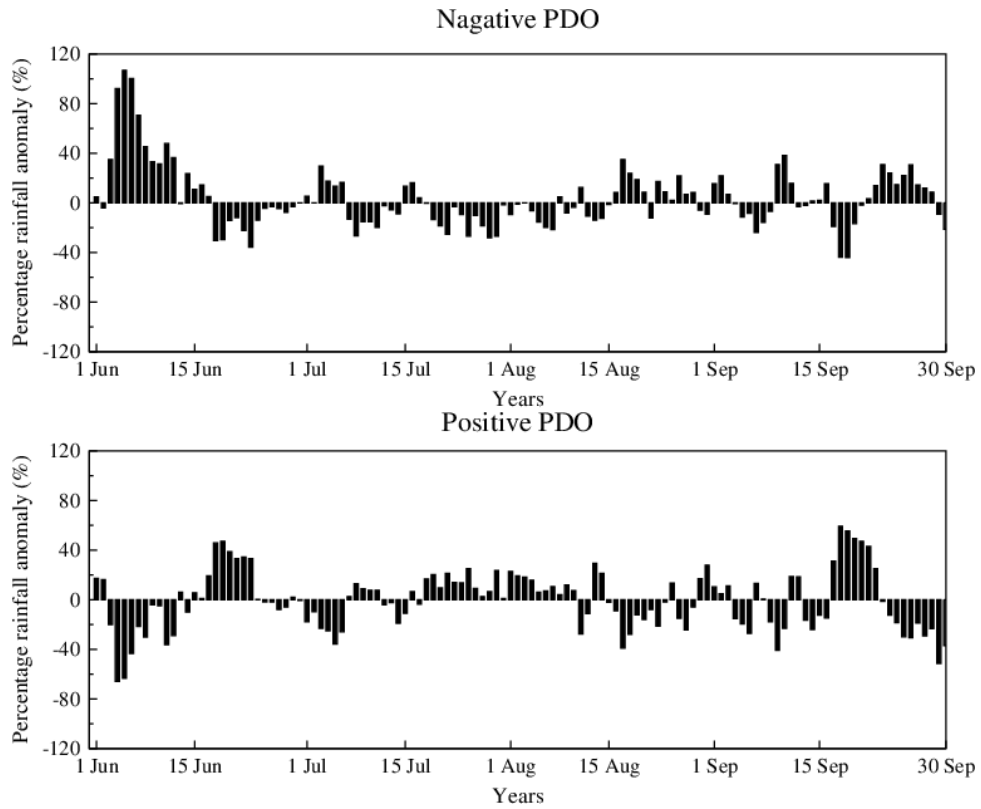


Figure 1.1: Daily variability in percentage rainfall anomaly (%) during negative phase of Pacific Decadal Oscillation (PDO) and positive phase of PDO

1.2 Trends in Aerosol optical properties over South Asia

Rohit Srivastava

Spatial variation of trends in MODerate resolution Imaging Spectroradiometer (MODIS) remote sensing-derived aerosol optical properties, namely, aerosol optical depth (AOD) at 0.55 μm and Ångström exponent (α) from 2001 to 2014, is estimated on annual and seasonal basis over South Asia. Positive trends in annual mean AOD are found over 56% area of continental regions of South Asia where remote sensing data could retrieve, while $\sim 40\%$ of Indian region show increasing trends in AOD (Figure 1.2). During winter and post-monsoon, $>70\%$ of the Indian subcontinent show positive trends in AOD due to increase in biomass burning emissions and owing to shallow boundary layer height during the seasons (Srivastava, 2016).

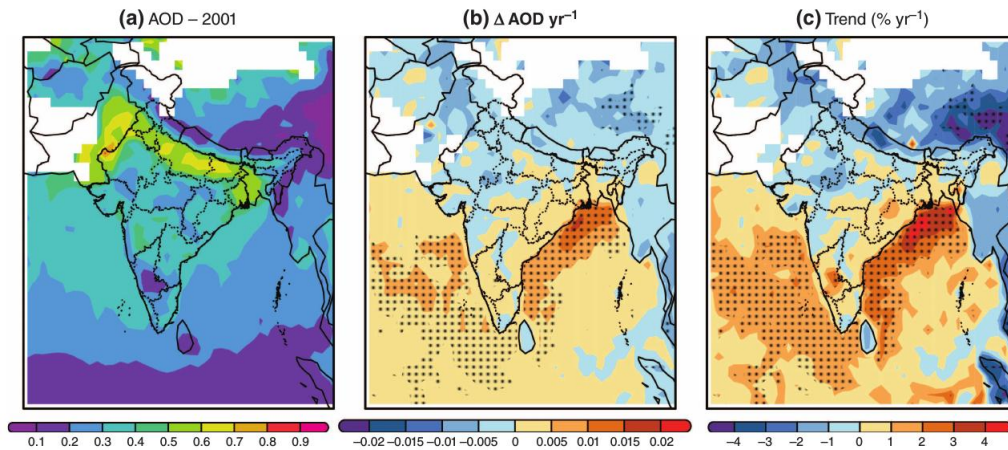


Figure 1.2: Annual mean mid-visible aerosol optical depth (AOD), (b) change in AOD year^{-1} , (c) percentage trend in AOD over the south Asian region. Dots indicate trends at 95% significance level. (Srivastava, 2016)

The increasing trends in both AOD and α over central, north and some part of south, east and northeast India are found, which corroborate that fine-mode aerosols are increasing over the regions. The AOD exhibits negative trends over northwest, north, central, west and east region of India; and Pakistan and Sri Lanka during pre-monsoon. The negative trends in AODs are found over maximum part of the South Asian continent during monsoon. The significant and strong positive trends in AOD (2–3% per year) and α are found in the Bay of Bengal (BoB) and the Arabian Sea,

moreover post-monsoon and monsoon seasons AODs exhibit significant and strong (>6% per annum) increasing trends in north BoB (Srivastava, 2016).

Such positive trends reveal the enhancement in the abundant of fine-mode aerosols in the oceanic regions. Spatial variabilities in the AOD and α trends give rise to significant differential radiative impact in the regions which affect the atmospheric dynamics and also influence the extreme events such as tropical cyclones in South Asian regions. The trend informations will be useful in improving the emission inventories and our understanding on aerosols in regional and global climate.

1.3 Investigation of role of physical and dynamical parameterizations on meteorology and aerosol properties in WRF-CHEM over Indian region

Sherin Hassan Bran and Rohit Srivastava

There are significant uncertainties associated to the physical and dynamical interaction with chemistry in regional climate models. In order to investigate the role of physical and dynamical parameterizations on meteorology and aerosol characteristics, Weather Research and Forecasting model coupled with Chemistry (WRF-CHEM) is utilized in the present study.

WRF-CHEM is one of the leading regional climate model using for meteorological and chemical simulations. There are about 25 micro-physics schemes along with multiple choices of planetary boundary layer, cumulus parameterization and diffusion schemes in WRF-CHEM v3.6.1. The suitable physical and dynamical schemes over the western and central Indian regions are not specified. In the present study, the simulations of WRF-CHEM for different schemes are compared with the observations to investigate the suitable schemes over the western and central Indian region.

The model simulations were performed for the year 2008 during the monsoon (June-July-August-September) season with 6 hourly boundary conditions obtained from Global Forecasting System (GFS). The anthropogenic emissions were obtained from Emissions Database for Global Atmospheric Research (EDGAR) with 0.1 x 0.1 degree resolution. The comparison of two different boundary layer schemes (MYJ and YSU) with the same cumulus (Grell 3D) and micro-physics (New Thompson) options suggested that black carbon (BC) mass concentrations in YSU were more closer to the observations when compared to MYJ scheme. The simulated precipitation rate over the region were found to be within 30% with respect to India Meteorological Department (IMD) observations in YSU scheme, while differences between observed and simulated precipitation in MYJ scheme were > 40%.

1.4 Terrestrial Net Primary Production (vegetation carbon storage) using Remote Sensing in Rukmavati River Basin

Shouvik Jha and Rohit Srivastava

Carbon dioxide (CO_2) gas is one of the major contributor to global warming and its continuous increasing trend is alarming (IPCC, 2013). Terrestrial vegetation plays a major role for sinking CO_2 from atmosphere. Net primary production (NPP) is the rate at which all the vegetations in an ecosystem produce net useful chemical energy by absorbing atmospheric CO_2 . NPP is equal to the difference between the rate at which the vegetations in an ecosystem produce useful chemical energy (GPP) and the rate at which they lose some of that energy during respiration.

Rukmavati River Basin (RRB) of Kachchh, Gujarat India (Figure 1.3) has arid climate with increasing salinity in irrigation water which make the basin less sustainable for agriculture. In view of above constraints, integrated Rukmavati River Basin development project was designed and implemented in 2010. In the project an integrated approach using the whole river basin as a basis for holistic and sustainable planning was implemented, which can provide a good solution to ensure Economic, Social and Environmental sustainability and ensure Food, Water and Energy security along with good quality of life.

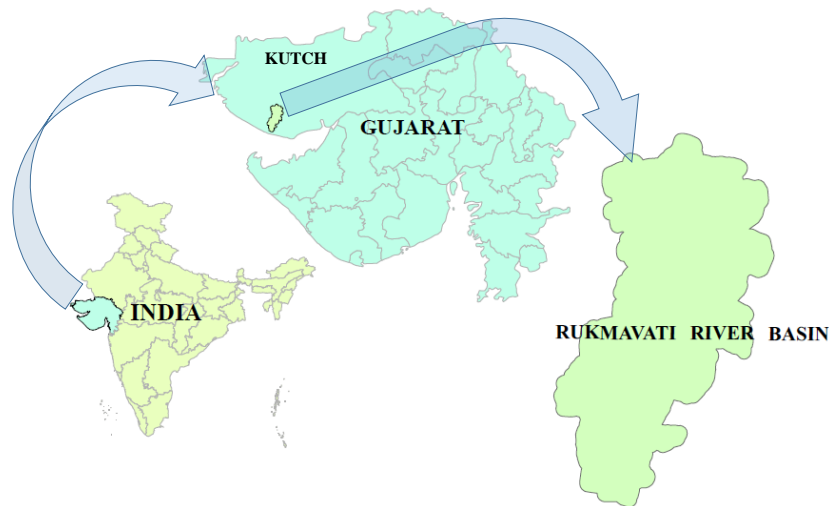


Figure 1.3: Map of India showing Gujarat state and Rukmavati River basin in map of Gujarat

The vegetation carbon storage are estimated using remote sensing (Landsat 8) data for post-monsoon (October) season of 2009 and 2014, to study the improvement in climate change mitigation due to improved agricultural activities done under Rukmavati River Basin (RRB) of Kachchh, Gujarat development program, which was started in 2010.

Carnegie Ames Stanford approach (CASA) (Field et al., 1995; Cramer et al, 1999) is utilized to determine the spatio-temporal variability of Net Primary Production during 2009 and 2014 over the study region. The NPP in whole basin was 2.5 Lakh ton C/Yr in 2009, which increased to 3 Lakh ton C/Yr in 2014 (Figure 1.4).

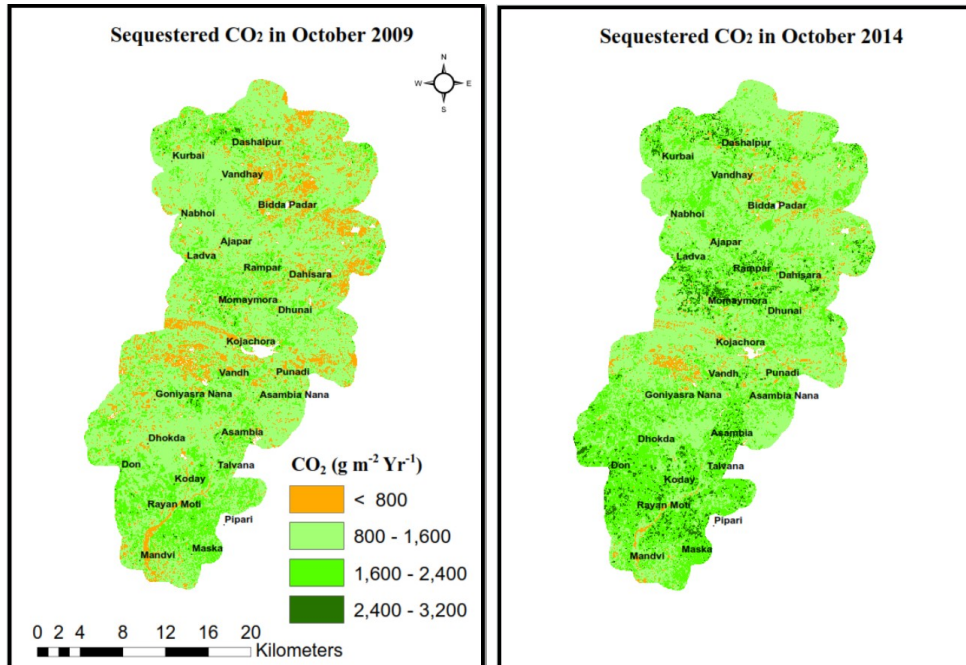


Figure 1.4: Spatial variation of equivalent CO_2 sequesters due to terrestrial vegetations in Rukmavati River Basin (RRB) of Kachchh, Gujarat, India during post-monsoon (October) 2009 and 2014.

The enhancement of 50 thousand ton C/Yr in 2014 is observed, which is 22% increase of NPP with respect to 2009. Such increment in NPP is owing to improvement in agricultural practices and tree plantations in RRB development program.

1.5 Role of El Niño on Southwest Monsoon of Gujarat

Prasannta Gadhavi ¹, Payal Gadhavi ² and Rohit Srivastava

ENSO (El Niño Southern Oscillation) is natural phenomenon, occurring at equatorial pacific region. El Niño exhibits when temperature of central pacific rises 0.5°C from normal condition, while during La Niña temperature falls by 0.5°C . El Niño and La Niña are Spanish words, mean ‘little boy’ and ‘little girl’ respectively and discovered by fishermen of Peru and Ecuador in South America. This occurs in late December and lasts within few weeks or months, or sometimes for longer duration also. El Niño is defined by average sea surface temperature anomaly in Niño-3.4 region (*i.e.*, $5^{\circ}\text{N} - 5^{\circ}\text{S}$, $120^{\circ} - 170^{\circ}\text{W}$) in the Pacific Ocean (Figure 1.6).

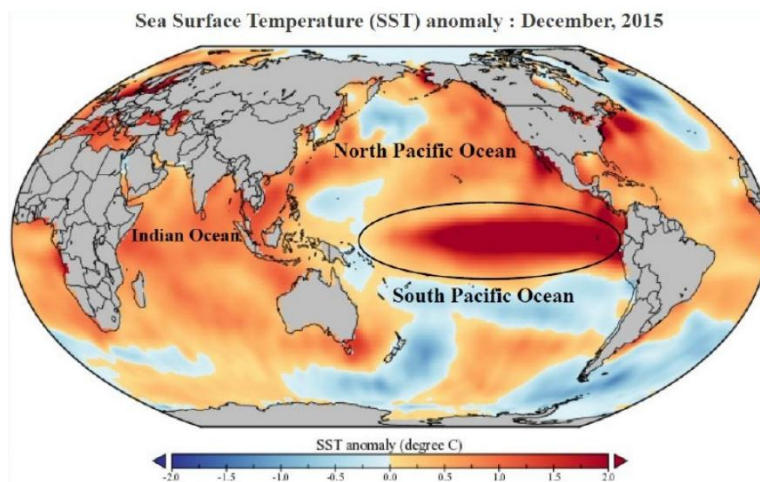


Figure 1.5: Sea surface temperature (SST) anomaly during December 2015. The warm SST in the Pacific ocean is also shown.

The pressure over eastern pacific decreases due to warming which causes reversal in trade winds. In addition, thermocline (layer separate warm water from cold deep water) becomes narrow in El Niño, due to suppressed upwelling. Due to these, the South America and Africa receive heavy rains, while India and Australia experience droughts during El Niño.

IMD (India Meteorological Department) gridded rainfall data over Gujarat region for 1991 to 2015 are utilized. There are eight El Niño occurred from 1991

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to 2015. The average rainfall over Gujarat region is found to be less than normal during more than 50% of El Niño years. Gujarat. However, in strong El Niño year 2015 north Gujarat including Kachchh and Amreli received more than 20% rain.

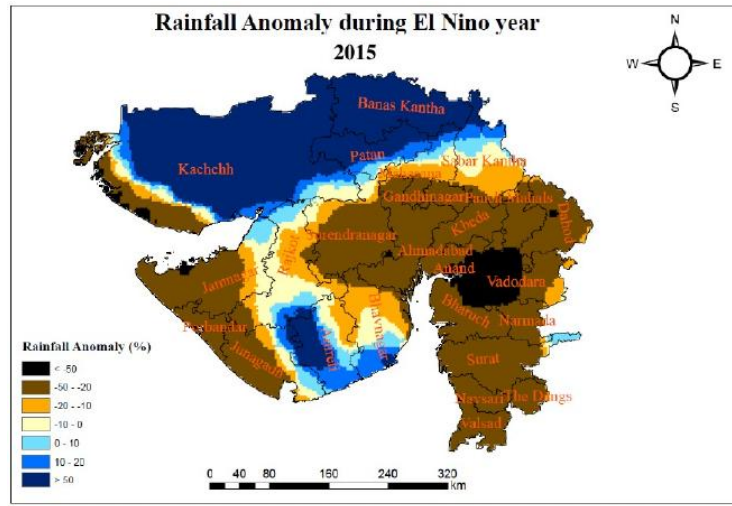


Figure 1.6: Percentage rainfall anomaly during Southwest monsoon (June-September) 2015.

References :

Cramer et al, 1999, Comparing global model of terrestrial net primary productivity; Overview and key results, *Glob. Change Biol.*, 5, 1-15.

Field C. B., Randerson J. T. and Malmstrom C. M., 1995, Global Net Primary Production: Combining Ecology and Remote Sensing, *Remote Sensing of Environment*, 55 (1), 74–88.

Intergovernmental Panel on Climate Change (IPCC), 2013. Clouds and Aerosols. In: *Climate Change 2013: The Physical Science Basis*. Boucher, O., et al. (2013), Stocker, T. F., et al. (Eds.), Cambridge University Press, Cambridge, U. K. and NY, U.S.A.

Srivastava R., 2016, Trends in aerosol optical properties over South Asia, *International Journal of Climatology*, 37, 1, DOI: 10.1002/joc.4710.

Chapter 2

Application and outreach activities

ICCSIR is involved in different outreach activities.

2.1 ICCSIR's weekly weather forecast bulletin

ICCSIR is releasing weekly weather forecast bulletin based on publicly available data and maps. The bulletin contains the spatial map of daily rainfall forecast over India and surrounding regions. The rainfall maps are generated from NCM-RWF's Global Forecast System (NGFS) model for 6 days forecast. 5 day forecast of weather parameter (rainfall, maximum and minimum temperature, total cloud cover, maximum and minimum relative humidity, wind speed and directions) over district centers of Gujarat and Maharashtra are provided in tabular form.

ICCSIR's weather bulletin was found to very helpful for farmers, social workers etc.

2.2 Dissemination of current weather data

The current morning and afternoon weather data have been recorded from the meteorological observatory installed at VRTI campus, Mandvi, Kachchh. The data are being disseminated to the farmers and para-workers of the region on each day.

2.3 Dissemination of Long Range Weather forecast

ICCSIR provided the Long-range weather forecast of Southwest Monsoon 2015 based on the India Meteorological Department (IMD) and World Meteorological Organization (WMO) and other forecasting agencies during April and June 2015. In the forecast, below average rainfall during monsoon 2015 was predicted which found to be correct over the Gujarat and Maharashtra region. This long-range forecast was very useful in planning different agricultural activities.

2.4 Satellite image over Agrocel Marine Chemical Division (MCD) at Dhordo, Kachchh

The satellite images of Dhordo area were obtained from Landsat 8 at a interval of 2 weeks. The raw images were processed and the images of horizontal resolution of 15 m were generated over the area of interest. These processed images is very useful in planning different activities at MCD, Agrocel Industries Ltd., Dhordo, Kachchh.

2.5 Training Programme

ICCSIR is involved in different farmers training program. ICCSIR provided the training on role of weather and climate on agriculture. ICCSIR also provided training on role of farmer in mitigating the climate change. Weather forecasts and its utilization for sustainable agriculture. ICCSIR also participated Farmer Training Workshop for Sustainable Agriculture organized by National Centre for Sustainable Development (NCCSD) under Central Research Institute on Dryland Agriculture (CRIDA) programme. This workshop was organized at four centers in Kachchh, Anand, and Navsari regions of Gujarat.

Chapter 3

Educational activities

ICCSIR participated in different educational activities in different places in India,

- ICCSIR staffs provided lectures on different courses on Environmental Science and Marine Science at Graduate level in Government Science College, Mandvi, Kutch.
- ICCSIR has participated in finalizing the content of different exhibitions on Climate Change in Science Express Climate Action Special (SE-CAS). ICCSIR is one of the knowledge partners of Centre for Environment Education (CEE) during the designing of SE-CAS.
- ICCSIR was involved in delivering lectures to students of different school/colleges on Weather and Climate.

Chapter 4

Research Publication and participation in conferences

ICCSIR published its research outcomes in various reputed International Journal such as:

- Absorbing and scattering aerosols over the source region of biomass burning emissions: Implications in the assessment of optical and radiative properties
Authors : Atinderpal Singh, Rohit Srivastava, Neeraj Rastogi, Darshan Singh
Journal : Atmospheric Environment, 127, 61-68, 2016.
- Trends in aerosol optical properties over South Asia
Author : Rohit Srivastava
Journal : International Journal of Climatology (IJOC), 37, 1, DOI: 10.1002/joc.4710, 2016
- Mixing States Of Aerosols Over Four Environmentally Distinct Atmospheric Regimes In Asia: Coastal, Urban, And Industrial Locations Influenced by Dust
Authors : S. Ramachandran and Rohit Srivastava
Journal : Environmental Science and Pollution Research (ESPR), 23: 11109, DOI: 10.1007/s11356-016-6254-8, 2016

ICCSIR participated in various Conferences/Seminars/Workshops such as:

- Invited talk on “Usefulness of weather Forecasting Communications in Agriculture”, in National Level workshop on Knowledge Multiplication and Mass communication for Agriculture in arena of Climate Change, Ahmedabad, Gujarat, India 27 October, 2015.

- Invite talk on “Role of Atmospheric Aerosols on Earth’s Climate” in Seminar on Climate change in Indian perspective at Department of Science, School of Technology, Pandit Deendayal Petroleum University (PDPU), Gandhinagar, Gujarat, India on December 23, 2015.
- **Best Oral presentation award** on “Estimation of terrestrial Net Primary Production using remote sensing : Rukmavati River Basin of Kachchh, Gujarat, India”, in Seminar on Climate change in Indian perspective at Department of Science, School of Technology, Pandit Deendayal Petroleum University (PDPU), Gandhinagar, Gujarat, India on December 23, 2015.
- ICCSIR participated in XXX GUJARAT SCIENCE CONGRESS (GSC) – 2016 Conference on “Challenges for Science and Technology Education During coming decades: Preparing for a Sustainable Gujarat” at K. S. K. V. Kachchh University, Bhuj during 06 – 07 February, 2016. ICCSIR has presented three posters in the GSC :
 1. Terrestrial Net Primary Production In Rukmavati River Basin of Kachchh, Gujarat by Shouvik Jha and Rohit Srivastava.
 2. Investigation of southwest Monsoon over Gujarat during El Niño by Prasannta Gadhavi, Payal Gadhavi (Govt. Science College, Mandvi) and Rohit Srivastava.
 3. Investigation of Tides at Mandvi Seacoast of Gujarat by Farhankhan M. Sindhi (Govt. Science College, Mandvi) and Rohit Srivastava
- Presentation at National Space Science Symposium (NSSS) – 2016 at Space Physics Laboratory (SPL), Thiruvananthapuram :
 - (i) Oral presentation ”Investigation of influence of decadal climate variability on Southwest Indian monsoon in CMIP5 simulations” by Rohit Srivastava (under MoES project).
 - (ii) Poster presentation ”Investigation of role of physical and dynamical parameterizations on meteorology and aerosol properties in WRF-CHEM over Indian region” by S.H. Bran and Rohit Srivastava (under DST project).

Chapter 5

Summary and Future plan

5.1 Summary

ICCSIR was involved on different research, outreach, training and education activities during 2015 -2016.

The major research finding during year 2015 - 2016 were as follows :

- Daily variations in rainfall anomaly show opposite characteristics during negative and positive phases of Pacific Decadal Oscillation (PDO). The above-normal rainfall (>25%) is found during the starting phase of monsoon in negative PDO.
- Positive trends in annual mean Aerosol Optical Depth (AOD) are found over 56% area of continental regions of South Asia where remote sensing data could retrieve, while $\sim 40\%$ of Indian region show increasing trends in AOD.
- The significant and strong positive trends in AOD (2–3% per year) and α are found in the Bay of Bengal (BoB) and the Arabian Sea. Such increase in fine aerosols may give rise to significant differential radiative impact in the regions which affect the atmospheric dynamics and also influence the extreme events such as tropical cyclones in South Asian regions.
- In Rukmavati River Basin, the enhancement of 50 thousand ton C/Yr in 2014 is observed, which is 22% increase of net primary production with respect to 2009. Such increment in vegetation carbon storage is owing to improvement in agricultural practices and tree plantations in Rukmavati River Basin (RRB) development program.

ICCSIR was involved in different education and outreach activities :

- Dissemination of ICCSIR's weekly weather forecasts on each Tuesday of the week.
- Dissemination of daily current weather data to para-workers and formers in Rukmavati River basin region.
- ICCSIR was providing high resolution satellite imagery over Dhordo Kutch to Marine Chemical Division of Agrocel Industries Ltd.
- ICCSIR was involved in different Training programmes on weather and agriculture.
- ICCSIR's staffs were also involved in educating graduate students of Government Science College, Mandvi, Kutch on Environmental and Marine Sciences.

5.2 Future Plan

ICCSIR will continue its education and outreach activities and participate in different training programs.

- Research on MoES and DST projects will continue.
- ICCSIR will be planning to research on weather forecasts and agro-met advisory over village level in Rukmavati River basin of Kutch, Gujarat region.
- Estimation of carbon dioxide (CO₂) sequestration due to improvements in agriculture in Gujarat.
- Estimation of water availability in water reservoirs using remote sensing data.