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4. **Brief bio data of the Investigators:** Enclosed

5. **Project Title:** Statistical Downscaling for hydro-climatic projections with CMIP5 simulations to assess Impacts of Climate Change

6. **Track Record and Workload Assessment of the PI**

**Schemes completed:**

Assessing Impact of Climate Change on Indian Subdivisional Rainfall, Funding Agency: IRCC, IIT Bombay. [2007-2010, Completed]

Multi-site Statistical Downscaling using Copula for Climate Change Impact Assessment on Hydrology, Funding Agency: Department of Science and Technology. [2008-2011, Completed, rated as "Excellent"]

Downscaling for Projections of Indian Rainfall and Temperature at high spatial Resolution, Funding Agency: Space Application Centre, Indian Space Research Organization (ISRO)

**Schemes ongoing:**

Assessing Impacts of Global and Local Changes on River Basin Scale Hydrology, Funding Agency: Space Technology Cell, IITB-Indian Space Research Organization (ISRO). [2009-2012, On-going]

Impacts of Global and Local Changes on the Rainfall in a Metro City, Funding Agency: Ministry of Water Resources, Govt. of India. [2011-2014, on-going]

7. **If the scheme is sanctioned, in whose name the cheque is to be issued:**

Registrar, IIT Bombay. (for IIT Bombay)

**8. Category of R&D Activity (Tick those which are appropriate):**

a. **Basic Research**
b. **Applied Research**√
c. **Action Research**
d. **Education and Training**
e. **Mass Awareness Programme**
f. **Infrastructure Development**
g. **Creation of Centres of Excellence**

## 9. Description of the Proposal

Climate change impacts assessment involves downscaling of coarse resolution climate variables simulated by General Circulation Model**s** (GCM**s**) using dynamic (physics based) **or** statistical (data-driven) approaches. Here, we propose statistical downscaling technique for projections of All India Monsoon Rainfall (AIMR) at a resolution of $0.5^0$/ $0.25^0$ in latitude/longitude. We propose to use kernel regression, Bias Correction Spatial Disaggregation (BCSD) and Artificial Neural Network (ANN) for the same. Coupled Model Intercomparison Project 5 (CMIP5) model outputs will be used for the same. Minimum 5 GCMs will be used to project the uncertainty. Multiple runs are also proposed for different GCMs. The projections for future will be made with multiple Representative Concentration Pathways (RCP) scenarios. The uncertainty resulting from the use of multiple scenarios and GCMs will be assessed and subsequently modelled. The projections will be made available in gridded format for further use in river basin scale hydrologic studies.

## 10. Objectives

*a) Finding answers to as yet un-answered questions:*

i. Future Meteorological at Finer Resolution: The primary focus of the proposed work is the use of GCM simulations of climate variables for projection of hydro-meteorologic variables with statistical downscaling in India. Such results will initiate the follow-on activities, such as, hydrologic modelling impacts of extremes, meteorological and agricultural drought assessment, water availability demand analysis etc.

ii. To assess the performance of the Coupled Model Intercomparison Project Phase 5 (CMIP5) simulations of GCMs in India.

iii. Modelling uncertainty considering the available CMIP5 simulations.

iv. To understand the geophysical processes related to Indian monsoon under changing climate, with data-driven models.

*b) Development of a new computational procedure*

Innovations in computational procedure involves

i) Development of multisite statistical downscaling approach to capture mean and standard deviation for each month at individual sites and also the spatial pattern.

ii) Parallel computing will be exercised for computationally expensive runs.

*c) Investigation of the behaviour of a natural process:*

i) The proposal aims to project future hydro-meteorological scenarios of Indian river basin, based on simulated meteorological and hydrological variables for future (next 100 years).

ii) To understand the impacts of local changes on micro-climate.

To summarize, the objectives of the proposed study are as follows:

I. Inter-comparison of IPCC climate model outputs (CMIP5) for assessing their relative skill in simulating rainfall patterns in Indian River Basin.

II. To project regional meteorological variables with statistical downscaling for future with different RCP scenarios.

III. Use of multiple downscaling techniques to understand the uncertainty

IV. To understand the capability of statistical downscaling in simulating spatial variability

V. Development of statistical downscaling and analysis model for extremes

VI. Modelling uncertainty resulting from multiple models, scenarios and downscaling methods.

VII. To prepare database of simulated data for further use in hydrologic models

## 11. Contribution to Water Resources Development

With several climate change initiatives, research works have been started in full phase on assessing impacts of climate change specifically on water resources and on different adaptation and mitigation approaches. The present work will provide the meteorological projections for next hundred years considering greenhouse emission scenarios. The results will be used in river basin scale climate change impacts assessment studies.

## 12. Putting the Research to Use

*a) Identify the possible end-users for the results of proposed research.*

The water resources community working in the field of climate change adaptation (i.e., water resources management for climate change scenarios) are the end users for the results of proposed research. The follow on works may include:

i) Assessment of Hydrologic impacts of climate change
ii) Agricultural water management and crop yield analysis
iii) Drought analysis and management
iv) Flood mitigation strategies for possible extreme rainfall
v) Optimal storage requirements for meeting future demands.

*b) List the actions that will be necessary to put the results to use.*

The size of the output (daily climate, meteorological and hydrologic variables), produced from this work will be huge. Initially we will try to maintain the data in the cluster and storage obtained through this project, and also give a copy to Ministry of Water Resources. Later, MOWR may need to take the responsibility to maintain the output for the follow-on researchers and water managers.

*c) List the difficulties/problems that may be encountered in putting the results to use.*

The data may directly be used in any studies with any publicly available software, which can read NETCDF format.

*d) Are the possible end users being involved in the research? if yes then describe how, if not then explain why not.*

The end users (river basin study researchers) will use the output of this project

## 13. Present State of Art

*a) Work at International Level:*

General Circulation Models (GCMs) are the tools designed to simulate time series of climate variables globally, accounting for the effects of the concentration of greenhouse gases in the atmosphere. Coupled with projections of $CO_2$ emission rates, they produce climate scenarios that can be described as 'pertinent, plausible representations of the future emissions of greenhouse gases and with the understanding of the effect of increased atmospheric concentration of the gases on global climate'. GCMs might capture large scale circulation patterns and correctly model smoothly varying fields such as surface pressure, but it is extremely unlikely that these models properly reproduce non-smooth fields such as precipitation. Additionally the spatial scale on which a GCM can operate is very coarse for hydrologic applications. Therefore, hydrologic implications of global climate change are usually assessed by downscaling appropriate predictors simulated by General Circulation Models (GCMs).

Methodologies to model the hydrologic variables at a smaller scale based on large scale GCM outputs are known as downscaling. The methodologies include dynamic downscaling, which uses complex algorithms at a fine grid-scale describing atmospheric process nested within the GCM outputs (commonly known as Limited Area Models or Regional Climate Models, RCM) and statistical downscaling, that produces future scenarios based on statistical relationship between larger scale climate features and hydrologic variables such as precipitation. The commonly used dynamic downscaling models are REGCM, WRF etc. In India, PRECIS, a dynamic downscaling model coupled with Hadley Climate Centre GCM is widely used.

Statistical downscaling methodologies can be broadly classified into three categories: weather generators, weather typing and transfer functions. Weather generators (Hughes and Guttrop, 1993; Wilks, 1999) are statistical models of observed sequences of weather variables. They can also be regarded as complex random number generators, the output of which resembles daily weather data at a particular location. Weather typing approaches involve grouping of local, meteorological variables in relation to different classes of atmospheric circulation. Future regional climate scenarios are constructed either by re-sampling from the observed variable distribution (conditioned on the circulation pattern produced by a

GCM), or by first generating synthetic sequences of weather pattern using Monte Carlo techniques and then re-sampling from the generated data. The mean or frequency distribution of the local climate is then derived by weighting the local climate states with the relative frequencies of the weather classes. The most popular approach of downscaling is the use of transfer function (Cannon and Whitefield, 2002) which is a regression based downscaling method that relies on direct quantitative relationship between the local scale climate variable (predictand) and the variables containing the large scale climate information (predictors) through some form of regression.

*b) Work at National Level:*

The work at national level mostly involve transfer function based approaches developed by Tripathi et al. (2006), Ghosh and Mujumdar (2006, 2007,2008,2009), Mujumdar and Ghosh (2008). These involve use of support vector machine, relevance vector machine etc. The uncertainty modelling is performed with non parametric approaches. The methodologies are further extended with kernel regression based approaches by Kannan and Ghosh (2010, 2013).

*c) Difference of the Proposed Work from Earlier Works:*

Although, in the last decade, there are some studies on hydrologic impacts of climate change, efforts have not been made to simulate climate, hydrologic and meteorological variables for near future and made them available for follow-on researchers. Furthermore, till now, there are many scientific questions unresolved, such as, identifying the partial impacts of SST increase, orography and land use change on rainfall trend, requirements of finer resolution climate models etc. Earlier literature on this specific topic may be considered as a routine work of either using dynamic downscaling model output in river basin hydrologic water quality quantity model or development of statistical downscaling with some uncertainty quantification. Extensive research works either on understanding the geophysics using multiple climate run experiments or use of rigorous statistics and data driven models for river basin scale finer resolution climate simulation have not yet performed. The proposed study focuses on these specific research issues and also aims to make all the outputs available for follow-on research works.

*c) References:*


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## 14. Methodology

The overall methodology, as presented in Fig. 1, is divided into four themes:

**A) Data collection and analysis**
**B) Kernel Regression based Statistical Downscaling**
**C) Bias Correction Spatial Disaggregation Method**
**D) Artificial Neural Network based Statistical Downscaling**
**E) Uncertainty Modeling**

Brief overview of all the modules with their sub-themes are presented:

**A) Data Collections and Analysis**

A1. *Data Collection and Compilation* (IITB, IITGN, IITG with the help of MOWR):
This includes collection of meteorological data (historical) throughout the country for the stations. **As there is an upper cap on the availability of data from IMD, the entire process of relaxation of the cap will be taken care by Ministry of Water Resources (after conversation with MOES)**. The participating institutes will then collect the data. For gridded rainfall and temperature, Aphrodite and IMD products will be used.

A2. Analysis of Observed Data (IITB, IITGN):
This includes analysis of patterns and trends of the historical data, data driven approaches to understand the geophysical processes associated with changing climate.

Trends/changes in seasonal means of precipitation, air temperature, soil moisture, evapotranspiration, and runoff will be estimated using the non-parametric Mann-Kendall trend method (Mishra et al., 2010). The spatial and temporal variability associated with the changes in meteorological variables will be studied. We will identify the changes in different hydrologic variables (soil moisture and runoff) that may attribute to the changes in climate forcings (precipitation and temperature) using the methodology described in Thompson et al.(2000).

A3. Evaluation of GCM (IITB, IITGN):
Evaluation of the CMIP5 simulations of GCMs is proposed in this sub-theme. The objective is to select better suit of GCMs among many, based on their performances in simulating the

climatology of the basin. Specific focus will be given to the simulations of interannual variability, periodicity due to Atlantic Multi-decadal oscillation (AMO), trends of climatic variables etc.

**B) Kernel Regression Based Downscaling (IITB)**

Statistical downscaling is the methodology by which coarse resolution predictors are linked to the fine resolution predictand using a statistical relationship. For the current study, we will adopt the methodology developed by Kannan and Ghosh [2012].Figure 1 provides a flowchart depicting the stepwise mathematical operations performed on the data for the rainfall projections. The GCM simulated predictors and the observed rainfall, as a predictand, undergo different mathematical operations before actually becoming statistically linked. The predictors undergo a bias correction operation where the systematic error is removed using a quantile based remapping technique [Li et al., 2010]. The bias corrected predictors go through a principal component analysis (PCA) that involves the application of orthogonal transformation on a set of correlated predictor variables, producing principal components. The resulting principal components are dimensionally reduced and uncorrelated to one another. Principal components carry almost the same variability as that of the original data. Hence, the PCA helps to reduce both dimensionality and multicollinearity. A reduction in the dimensions also results in a reduction in the computational effort.

A K-means clustering technique is applied in order to individually derive the daily rainfall states for the seven Indian zones. The step helped to reserve cross-correlation amongst rainfall for multiple grids in one zone. The daily rainfall states and the bias corrected predictors, that all undergo principal component analysis, are key inputs to the kernel regression model for establishing the statistical relationship for the training period. Assuming that the relationship holds for the future, future states can be generated with the help of pre-

established relationships and predictors for the future period. By applying a nonparametric kernel regression, rainfall is projected at each node.

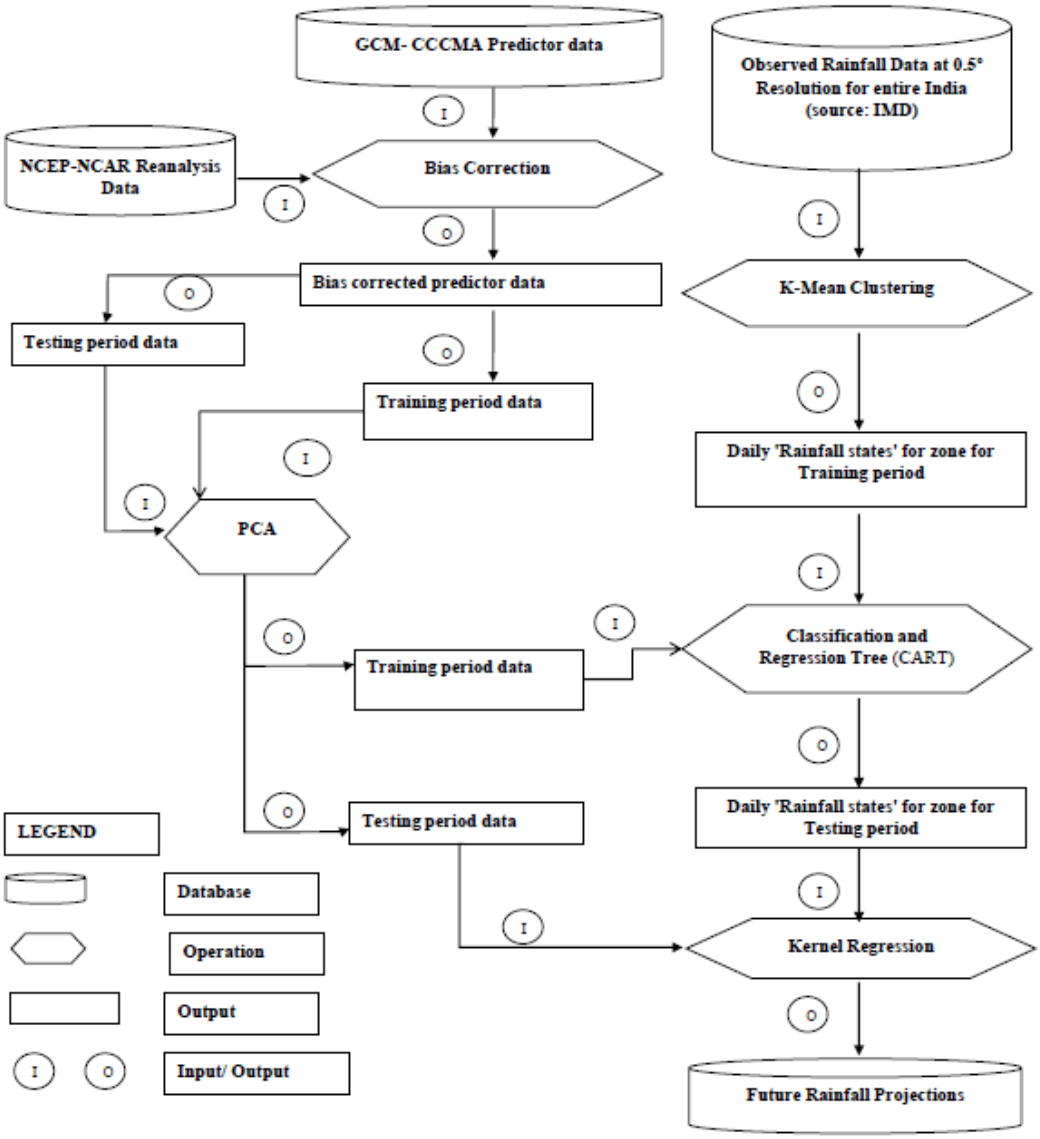


**Fig 1. Kernel Regression Based Downscaling**

## C) Bias Correction Spatial Disaggregation (IITGN)

The proposed work will address the following science questions:

- To what extent downscaled and bias corrected projections using the BCSD approach will resolved the fine scale information in the climate variables

(Precipitation, maximum and minimum air temperature) in watersheds in the Indian sub-continent region?

- How will downscaled and bias corrected projections of precipitation , maximum and minimum air temperature differ from those obtained from the raw GCMs output?
- To what extent will uncertainty associated with the inter-model variations reduce in the bias corrected and spatially downscaled projections at the watershed scale?

The monthly precipitation, maximum and minimum air temperature data will be obtained for the selected GCMs from the CMIP5 website for the period of 1950-2100. The periods 1950-2005 and 2006-2100 will represent the historic and future climate, respectively. Data from the CMIP5 models will be bias-corrected and spatially downscaled using the approach described in Wood et al. [2002, 2004] and Maurer, [2007]. The BCSD approach is based on quantile-based mapping of the probability density functions of monthly data onto spatially aggregated gridded observed data. Observed precipitation, maximum and minimum air temperature data will be spatially aggregated at 1° spatial resolution. The step-wise procedures of the BCSD approach are provided in Wood et al. (2002; 2004).

**D) ANN based Downscaling (IITG and IITK)**

The most of the ANN models used for downscaling of GCM data are the Multilayer Perceptron network (MLP) trained using standard backpropagation algorithm. The simplicity and ability of the MLP to transform input data into desired response has made it a popular pattern-classification tool. But quite often MLP yields sub-optimal

solutions due to several limitations like getting trapped in local minima, large number of epochs, over-fitting of data and large computational time. These limitations can be overcome by using Generalized Regression Artificial Neural Network (GRNN) model. In this present study, the MLP model trained with standard back propagation algorithms will be initially tried. However, the applicability and efficiency of the GRNN model will also be evaluated in case of downscaling of GCM data.

**E) Uncertainty Modeling (IISc)**

Meteorologic projection to assess impacts of climate change is characterized by multiple sources of uncertainties resulting from the use of multiple models, scenarios and downscaling methods. We propose to use multi-model average, super ensemble and Bayesian methods for handling multiple projections.

**15. Cost Estimates:**

| **Institute** | **Amount (INR)** |
|---|---|
| Indian Institute of Technology Bombay | 13233544 |
| Indian Institute of Technology Guwahati | 5789497 |
| Indian Institute of Science, Bangalore | 3807899 |
| Indian Institute of Technology Gandhinagar | 10568235 |
| Indian Institute of Technology Kanpur | 1794275 |
| **Total** | **35193450** |

***IIT Bombay***

Total Cost of the project including over head charges (if any): INR 1,28,64,380
15.1 Subhead wise Abstract

| Subhead | Amount (Rs.) |
|---|---|
| **Salary** | 15,91,200 |
| **TE** | 75,000 |
| **Infrastructure/Equipment** | 1,04,00,000 |
| **Sub Total** | 12066200 |
| **Add Contingency 5%** | 603310 |
| **Total** | 12669510 |
| **Institutional over heads (calculated following the norms subject to total 15 Lakhs)** | 564034 |
| **Grand Total** | 1,32,33,544 |

***(****Note:* ***In this table of abstract, it is not necessary to indicate year wise provisions. The release of funds will be tied down with milestones of progress and not with passage of time)***

15.2 Justification for Institutional Over Head charges.

Institutional overhead charges are required for infrastructural facility and maintenances.

15.3 Amount sought to be released at the start of the work with justification.

To start the work the first year funding may be released.

15.4 Subheads wise Details

**Salary**

| Designation | Year 1 | | | Year 2 | | |
|---|---|---|---|---|---|---|
| | Rate/ Month | Month | Amount | Rate/ Month | Month | Amount |
| 1 SRF | 28,000 pm/ head + 30% HRA | 12 | 436800 | 28,000 pm/ head + 30% HRA | 6 | 218400 |
| 1 RA (III) | 40,000 pm + 30% HRA | 12 | 624000 | 32,000 pm + 30% HRA | 6 | 312000 |
| Totals | | | 10,60,800 | | | 5,30,400 |

15.5 Man- months utilisation table

RA (III)

| Months | Activities |
|---|---|
| 1-3 | Understanding Downscaling and literature review |
| 4-6 | Data Collection and coding |
| 7-9 | GCM output downloading and bias correction |
| 10-12 | Statistical downscaling |
| 13-15 | Extremes downscaling |

| | |
|---|---|
| 16-18 | Output file preparation |

SRF

| Months | Activities |
|---|---|
| 1-3 | Arrangements for procurement of cluster |
| 4-9 | Cluster set up |
| 10-18 | Managing Cluster Optimizing the codes and output file management |

15.6 Travel Expenditure (TE): Rs 75,000/-

| S. No. | Particulars | Year I | Year II | Total |
|---|---|---|---|---|
| A | Attending the review meeting/ conference | 50000 | 25000 | 75000 |

**15.7 Infrastructure (Purchased items of a permanent nature like equipment, software or data; construction of any buildings etc.)**

| Sl. No. | Equipment | Quantity | Cost (Rupees) | Proposed year of purchase |
|---|---|---|---|---|
| 1 | Computing cluster with high storage (Details mentioned below) | 1 | 80,00,000 | 1st |
| 2 | Port for output sharing and cluster communication between multiple institutions | 1 | 10,00,000 | 1st |
| 2 | Workstation/ PCs | 3 | 3,00,000 | 1st |
| 3 | Data (Satellite and meteorologic data, to be shared with other team members) | | 11,00,000 | 1st |
| | Total | | 1,04,00,000 | |

**Justifications for Storage and computing clusters**

Number of GCMs: 32

Scenarios: historical, 2.5,4.5 and 8.5 , total 4 runs

Initial conditions for each GCM and each scenario: 10

Total runs: 32*4*10= 1280.

Variables= 20 (predictors at different pressure levels)

Each variable data size= 1 GB

Total storage requirement for GCM output: 25600 GB = 25 TB

Total = 25 TB

Backup of entire set= 25 TB

Total 50 TB

Running downscaling models for 800 runs needs high performance computing facility and hence a small cluster will be required to make the work complete in all respect.

**IIT Guwahati**

| Subhead | Amount (Rs.) |
|---|---|
| **Salary** | 17,38,800 |
| **TE** | 5,00,000 |
| **Infrastructure/Equipment** | 23,00,000 |
| **Experimental Charge** | 7,40,000 |
| **Sub Total** | 52,78,800 |
| **Add Contingency 5%** | 2,63,940 |
| **Total** | 55,42,740 |
| **Institutional over heads (maximum of 5 Lakhs or 20%)** | 2,46,757 |
| **Grand Total** | 57,89,496 |

**Budget Break up**

Budget for staff

| Designation & number of persons | Monthly Emoluments | BUDGET | | | (in Rupees) |
|---|---|---|---|---|---|
| | | 1st Year | 2nd Year | 3rd Year | Total |
| 3 nos of J.R.F. (M Tech) | 26,000/- +20% HRA +1000/- Medical Allowance =32,200/- | 11,59,200/- | 5,79,600/- | | 17,38,800 |

Budget for travel

| | BUDGET | | | (in Rupees) |
|---|---|---|---|---|
| | 1st Year | 2nd Year | 3rd Year | Total |
| Travel | 2,50,000/- | 2,50,000/- | | 5,00,000/- |

Budget for equipment

| Sl. No. | Generic name of the Equipment along with make & model | Estimated Costs |
|---|---|---|
| 1 | Statistica Data Miner version 11.0 under MS Windows, Five User Desktop License | 7,00,000/- |
| 2 | 3 nos of work station (i7, 1TB, 20GM RAM) | 15,00,000/- |
| 3 | Personal Computer/Laptop (2 nos @Rs. 40,000) | 80,000/- |
| 4 | Portable scanner (1 no @ Rs. 10,000) | 20,000/- |
| | Total | 23,00,000/- |

Experimental Charge

| | Year 1 | Year 2 | | |
|---|---|---|---|---|
| Field Data Collection | 1,20,000/- | 1,20,000/- | | 2,40,000/- |

| | | | | |
|---|---|---|---|---|
| Workshop | | 5,00,000/- | | 5,00,000 |
| Total | | | | 7,40,000 |

***IISc, Bangalore***

| **Components** | **Year1** | **Year2** | **Total** |
|---|---|---|---|
| **Salary:** RA-III 2 @ 40000 per month+ 30% HRA | 12,48,000 | 6,24,000 | 18,72,000 |
| **Equipment:** 8 PCs/ Laptops (high speed) | 8,00,000 | | 8,00,000 |
| **Experimental Charges** | 3,50,000 | 3,50,000 | 7,00,000 |
| **Travel** | 50,000 | 50,000 | 1,00,000 |
| **Contingency** | 122400 | 51200 | 173600 |
| **Subtotal** | **25,70,400** | **10,75,200** | **36,45,600** |
| **Overhead** | | | 1,62,299 |
| **Total** | | | **38,07,899** |

***IIT Gandhinagar***

| **Components** | **Year1** | **Year2** | **Total** |
|---|---|---|---|
| RA-III 1 @ 40000 per month+ 30% HRA | 6,24,000 | 3,12,000 | **9,36,000** |
| **Equipment:** | | | **86,00,000** |
| Computational Cluster | 80,00,000 | | |
| Storage @ 50 TB | 2,00,000 | | |
| 1 PC/ Laptop | 1,00,000 | | |
| Data | 1,00,000 | 2,00,000 | |
| **Travel** | 50,000 | 50,000 | **1,00,000** |
| Contingency | 453700 | 28100 | 481800 |
| Subtotal | 95,27,700 | 5,90,100 | 1,01,17,800 |
| Overhead | | | 4,50,435 |
| **Total** | | | **1,05,68,235** |

***IIT Kanpur***

| **Components** | **Year1** | **Year2** | **Total** |
|---|---|---|---|
| RA-III 1 @ 40000 per month+ 30% HRA | 6,24,000 | 3,12,000 | **9,36,000** |
| **Equipment:** Computer/ laptop and storage | 4,00,000 | | 4,00,000 |
| **Experimental Charges** | 1,00,000 | 1,00,000 | 2,00,000 |
| **Travel** | 50,000 | 50,000 | 1,00,000 |
| **Contingency** | 58700 | 23100 | 81800 |
| **Subtotal** | 12,32,700 | 4,85,100 | 17,17,800 |
| **Overhead** | | | 76,475 |
| **Total** | | | **17,94,275** |

**16. Work Schedule**

**a) Probable Date of Commencement:** From the date of acceptance

**b) Duration of Study:** 18 Months

**c) Stages of Work and Milestones:**

| Activities | Month 1-3 | Month 4-6 | Month 7-9 | Month 10-12 | Month 13-15 | Month 16-18 |
|---|---|---|---|---|---|---|
| | | | | | | |
| 1.Literature Review | | | | | | |
| 2. Data Collection | | | | | | |
| 3. GCM Output preparation | | | | | | |
| 4. Coding | | | | | | |
| 5. Downscaling | | | | | | |
| 6.Extremes | | | | | | |
| 7.Uncertainty Modeling | | | | | | |
| 8. Output Data formatting | | | | | | |
| 9. Report Writing | | | | | | |

**d) Release of funds:**

At the starting of work, the first year fund may be released. After reaching first 5 milestones, the second (last) installment may be released.

Declaration

1. I have carefully read the terms and conditions of the research grant ami agree to abide by them.
2. This is to certify that I have neither.submitted this proposal elsewhere for financial support nor have undertaken it at the request of any commercial agency) or as a consultancy.

**Date 05 July 2015**

**Time 12 noon** **Signature of PI**

Endorsement form the Head of the institution

1. The Institute/ Organisation welcome the participation of *Subimal Ghosh* as Principal Investigator for above project.
2. The necessary equipment and institutional support as described in item 15.2 will be made available as and when required for the purpose of the project to ensure that the work is taken upto on priority and completed on schedule.
3. In the event of foreclosure/discontinuation/cancellation of the scheme for any reason, the entire amount released for the scheme will be fully refunded to the MoWR along with the interest prescribed till the date of return by the institute/organisation.
4. The Register of permanent and semi-permanent assets acquired out of grants from MoWR will be maintained in Form GFR-19.
5. The assets acquired out of this grant shall be transferred to the desired destination in good & working condition as and when required.

Date
Place

Signature
Head of the Institution

भारतीय प्रौद्योगिकी संस्थान मुंबई
पवई, मुंबई - 400 076, भारत
**Indian Institute of Technology Bombay**
Powai, Mumbai - 400 076, India

दूरभाष/Phone : (+91-22) 2572 2545
फैक्स/Fax : (+91-22) 2572 3480
वेबसाईट/Website : www.iitb.ac.in

IIT Bombay

## ENDORSEMENT FROM THE HEAD OF THE ORGANISATION

(*To be typed on the letter-head of the organization*)

**Project Title:** Statistical Downscaling for hydro-climatic projections with CMIP5 simulations to assess Impacts of Climate Change

1. The Institute welcomes the participation of **Dr. Subimal Ghosh** from Dept. of Civil Engineering as the Principal Investigator for the above project.

2. The necessary equipment and institutional support as described in item 15.2 will be made available as and when required for the purpose of the project to ensure that the work is taken upto on priority and completed on schedule.

3. The Registrar of permanent and semi-permanent assets acquired out of grants from MoWR will be maintained in Form GFR-19.

14/7/15

**Date July 14, 2015**
**Place: IIT Bombay**

**Signature**
**(Head of the Institute)**

सह. संकायाध्यक्ष, शोध एवं विकास
Associate Dean, Research and Development
कृते निदेशक, आय आय टी मुंबई
For Director, IIT Bombay

**Endorsement from collaborating Institution/Agency**

I have gone through the Research proposal entitled "Statistical Downscaling for hydro-climatic projections with CMIP5 simulations to assess Impacts of Climate Change" submitted by Prof. P. P. Mujumdar of Indian Institute of Science for MoWR funding and noted the obligations and responsibilities indicated in our name which are as below :

a. Proposed activities of research work (list activities)
   **Uncertainty Modeling**

b. Estimated cost for the proposed activities: Rs **38,07,899**

c. Share of Overhead charges and Contingency(Taken together) Rs. **3,25,899**

I hereby affirm that my organization is committed to participate in the research scheme to the full extent with above mentioned obligations and responsibilities.

**(Head of the collaborating Institution/Agency)**

REGISTRAR
INDIAN INSTITUTE OF SCIENCE
BANGALORE - 560 012

**Seal/Stamp**

**Date** 03 July 2015
**Place** Bangalore

भारतीय प्रौद्योगिकी संस्थान गाँधीनगर
विश्वकर्मा शासकीय अभियांत्रिकी महाविद्यालय परिसर,
चाँदखेडा, अहमदाबाद, गुजरात – 382 424
INDIAN INSTITUTE OF TECHNOLOGY GANDHINAGAR
Vishwakarma Government Engineering College Campus,
Chandkheda, Ahmedabad, Gujarat - 382 424

Office : +91 79 3245 9896
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Website : http:\\www.iitgn.ac.in

IIT GN

**Surya P. Mehrotra**
Professor-in-charge R & D, &
Professor-in-charge External Relations

## Endorsement from collaborating Institution/Agency

I have gone through the Research proposal entitled **Statistical Downscaling for hydro climatic projections with CMIP5 simulations to assess Impacts of Climate Change** submitted by **Prof. Vimal Mishra** of **Indian Institute of Technology (IIT) Gandhinagar** for MoWR funding and noted the obligations and responsibilities indicated in our names which are as below:

a. Proposed activities of research work
**Analysis and development of bias correction and downscaled climate projections for India at a high resolution**

b. Estimated cost for the proposed activities (mention amount in Rs.)
**INR 1,05,68,235**

c. Share of Overhead charges and Contingency(Taken together)
**INR 9,32,235**

I hereby affirm that my organization is committed to participate in the research scheme to the full extent with above mentioned obligations and responsibilities.

**(Head of the collaborating Institution/Agency)**
**Seal/Stamp**

**Professor-in-Charge**
**Research & Development**
**Indian Institute of Technology Gandhinagar**
**Chandkheda,**
**Ahmedabad-382 424**

**Date – 07-07-2015**
**Place- Ahmedabad**

भारतीय प्रौद्योगिकी संस्थान गुवाहाटी,
गुवाहाटी-781 039

**Indian Institute of Technology Guwahati,**
Guwahati-781 039

Phones :
Direct : 361- 2582082, 2852135
Fax : 361-2582089

**Ref.: R&D/CE/P/AKS/2015-16/** **Date : 16.07.2015**

## Endorsement from the Head of Institution

**Title of the Project: "Statistical downscaling for hydro-climatic projections with CMIP5 simulations to assess impacts of climate change"**

I have gone through the research proposal entitled "Statistical downscaling for hydro-climatic projections with CMIP5 simulations to assess impacts of climate change" submitted by Prof. Arup Kumar Sarma, Prof Rajib Kr. Bhattacharjya and Dr. Manish Kr. Goyal of Indian Institute of Guwahati for MoWR funding and noted the obligations and responsibilities indicated in our name which are as below:

a. Proposed activities of research work (list activities)

**ANN Based Downscaling**

b. Estimated cost for the proposed activities : Rs. 57,89,497.00
c. Share of overhead charges and contingency (Taken together): Rs. 5,10,697.00

I hereby affirm that my organization is committed to participate in the research scheme to the full extent with above mentioned obligations and responsibilities.

17/7/15

**Head of the collaborating institution**
सकायाध्यक्ष, अनुसंधान एवं विकास
Dean, Research and Development
भारतीय प्रौद्योगिकी संस्थान गुवाहाटी
Indian Institute of Technology Guwahati
गुवाहाटी-781039
Guwahati-781039

**Dated:**

**Place:**

भारतीय प्रौद्योगिकी संस्थान कानपुर
अधिष्ठाता अनुसंधान एवं विकास कार्यालय
**Indian Institute of Technology Kanpur**
**Dean of Research & Development (DORD) Office**

**डॉ. अमलेन्दु चन्द्र**
अधिष्ठाता, अनुसंधान एवं विकास
आचार्य, रसायन विभाग
**Dr. Amalendu Chandra**
Dean of Research & Development
Professor, Department of Chemistry

**Annexure-2**

**Endorsement from Indian Institute of Technology Kanpur**

I have gone through the Research proposal entitled *Statistical Downscaling for hydro-climatic projections with CMIP5 simulations to assess Impacts of Climate Change* submitted by Dr. Ashu Jain of Indian Institute of Technology Kanpur for MoWR funding and noted the obligations and responsibilities indicated in our name which are as below:

a. Proposed activities of research work

   ANN based Downscaling

b. Estimated cost for the proposed activities

   Rs. 17,94,275/=

c. Share of Overhead charges and Contingency (Taken together)

   Rs. 1,58,275/=

I hereby affirm that my organization is committed to participate in the research scheme to the full extent with above mentioned obligations and responsibilities.

A Chandra 6/7/15

अधिष्ठाता
DEAN
अनुसंधान एवं विकास
Research & Development
आई० आई० टी० कानपुर
I.I.T. Kanpur

**(Head of the collaborating Institution/Agency)**
**Seal/Stamp**

Date: July 6, 2015
Place: IIT Kanpur

Address : Indian Institute of Technology Kanpur, Kanpur - 208 016, INDIA
कार्यालय: Office: +91-512-2597578, 2597241 (O) 2598446 (R) • Fax: +91-512-2590260
ई-मेल: e-mail: dord@iitk.ac.in
पत्रालय : आई0आई0टी0 कानपुर-208016 (भारत)
P.O.: I.I.T., KANPUR - 208016 (India)

**Resume of PIs**

## SUBIMAL GHOSH (PhD, IISc, 2007)

**Assistant Professor**
**Department of Civil Engg.,**
**Indian Institute of Technology, Bombay**
**Mumbai – 400 076, India.**

**Office: +91 22 2576 7319; Fax: +91 22 2576 7302**
**Mobile: +91 99306 63969**
**E-Mail: subimal@civil.iitb.ac.in**
**subimal.ghosh@gmail.com**

## EMPLOYMENT

Assistant Professor in Department of Civil Engineering, IIT Bombay from 16th November, 2007.

## RESEARCH GUIDANCE

PhD Student: 1 (thesis submitted), 6 (ongoing)
Masters Student: 2 (completed), 1 (ongoing)

## SPONSORED RESEARCH PROJECTS (AS PRINCIPAL INVETIGATOR)

1. Assessing Impact of Climate Change on Indian Subdivisional Rainfall, Funding Agency: IRCC, IIT Bombay. [2007-2010, Completed]
2. Multi-site Statistical Downscaling using Copula for Climate Change Impact Assessment on Hydrology, Funding Agency: Department of Science and Technology. [2008-2011, Completed, Final report pending, rated as "Excellent"]
3. Assessing Impacts of Global and Local Changes on River Basin Scale Hydrology, Funding Agency: Space Technology Cell, IITB-Indian Space Research Organization (ISRO). [2009-2012, On-going]
4. Downscaling for Projections of Indian Rainfall and Temperature at high spatial Resolution, Funding Agency: Space Application Centre, Indian Space Research Organization (ISRO). [2011-2012, Completed]
5. Impacts of Global and Local Changes on the Rainfall in a Metro City, Funding Agency: Ministry of Water Resources, Govt. of India. [2011-2014, on-going]

## PUBLICATIONS (10 SIGNIFICANT)

1. Subimal Ghosh, Das, D., Kao, S-c and Ganguly, A. (2012), Lack of uniform trends but increasing spatial variability in observed Indian rainfall extremes, Nature Climate Change
2. Kannan, S. and Subimal Ghosh (2011), Prediction of daily rainfall state in a river basin using statistical downscaling from GCM output, Stochastic Environmental Research and Risk Assessment, Springer. DOI 10.1007/s00477-010-0415-y
3. Subimal Ghosh (2010), SVM-PGSL coupled approach for statistical downscaling to predict rainfall from GCM output, Journal of Geophysical Research, 115, D22102, doi:10.1029/2009JD013548.
4. Kashid S, Subimal Ghosh and Maity R. (2010), Streamflow prediction using multi-site rainfall obtained from hydroclimatic teleconnection, Journal Of Hydrology, 395, pp 23-38, doi:10.1016/j.jhydrol.2010.10.004

5. Subimal Ghosh (2010), Modelling bivariate rainfall distribution and generating bivariate correlated rainfall data in neighbouring meteorological subdivisions using copula, Hydrological Processes, 24, 3558-3567
6. Subimal Ghosh, Luniya, V. and Gupta, A. (2009), Trend Analysis of Indian Summer Monsoon Rainfall at Different Spatial Scales, Atmospheric Sciences Letter, Royal Meteorological Society, 10(4), pp. 285-290
7. Subimal Ghosh and P. P. Mujumdar (2009), Climate Change Impact Assessment-Uncertainty Modeling with Imprecise Probability, Journal of Geophysical Research- Atmosphere (AGU), 114, D18113, doi:10.1029/2008JD011648
8. Mujumdar, P. P., and S. Ghosh (2008), Modeling GCM and scenario uncertainty using a possibilistic approach: Application to the Mahanadi River, India, Water Resources Research, 44, W06407, doi:10.1029/2007WR006137.
9. Subimal Ghosh and P. P. Mujumdar (2008), "Statistical Downscaling of GCM Simulations to Streamflow using Relevance Vector Machine", Advances in Water Resources, 31(1), pp. 132-146.
10. Subimal Ghosh and P. P. Mujumdar, (2007), "Nonparametric Methods for Modeling GCM and Scenario Uncertainty in Drought Assessment", Water Resources Research, AGU, 43, W07405, doi:10.1029/2006WR005351.

## AWARDS AND RECOGNITIONS

1. Reviewer of IPCC AR5 WG II Report
2. Editorial Board Member of The Scientific World Journal
3. Young Scientist Award 2012 from Indian National Science Academy (INSA) in "Engineering and Technology"
4. Young Investigator Award 2012 from Industrial Research & Consultancy Centre, Indian Institute of Technology Bombay, Mumbai
5. Indian National Academy of Engineers (INAE) Young Engineer Award 2011.
6. Institute of Engineers (India) Young Engineer (Civil) Award 2011
7. The outstanding reviewer award for Journal of Hydrologic Enginnering, American Society of Civil Engineers (ASCE), 2010.
8. BOYSCAST Fellowship (2009-10) from Department of Science and Technology, to work in Oak Ridge National Laboratory, TN, US
9. Indian Science Congress Association Young Scientist Award for 2009-2010 in "Engineering Sciences"
10. Prof. N S Govinda Rao Medal Best Ph. D. Thesis Award 2007 from Department of Civil Engineering, Indian Institute of Science, Bangalore.
11. Fast Track Project Grant for Young Scientists from Science and Engineering Research Council (SERC), Department of Science and Technology (DST), India (2007)

Name : **Pradeep Mujumdar**

Date of Birth : 04 November 1958
Sex : Male
Nationality : Indian
E-mail : pradeep@civil.iisc.ernet.in Phone : +91 80 2293 2323
Web : http://civil.iisc.ernet.in/~pradeep.html

**Academic Degrees**

| | | |
|---|---|---|
| 1981 | B.Tech. | KREC Surathkal (Mysore University) |
| 1984 | M.Tech | Indian Institute of Technology, Kharagpur |
| 1989 | Ph.D. | Indian Institute of Science, Bangalore |

**Professional Experience**

| Period | Position | Name of the Institute |
|---|---|---|
| Aug. 1989 - Nov.1990 | Lecturer | Indian Institute of Technology Bombay, India |
| Nov. 1990 - Jun. 1992 | Assistant Professor | Indian Institute of Technology Bombay, India |
| Jun. 1992 – Jun. 1998 | Assistant Professor | Indian Institute of Science Bangalore, India |
| Jun. 1998 - Jun. 2004 | Associate Professor | Indian Institute of Science Bangalore, India |
| Jun. 2004 – Date | Professor* (Chairman, Civil Engg Nov 2006-Dec 2010) | Indian Institute of Science Bangalore |

***** Also, Associate Faculty, Divecha Center for Climate Change ((Aug 2008 – date) and Associate Faculty, Center for Earth Sciences (Sep 2007 – date) , IISc Bangalore

**Synergetic Activities and Recognition**

- Chair Professor (KSIIDC), Energy and Mechanical Sciences, IISc (Jul.2012-date).
- Distinguished Visiting Fellowship, Royal academy of Engineering, UK (2011)
- Member, Editorial Board, *Advances in Water Resources* (Pub : Elsevier, Netherlands) (Aug. 2009 – date)
- Member, Editorial Board, *Sadhana*, Academy Proceedings in

Engineering Sciences, Indian Academy of Sciences (2012-date).

- Reviewer, IPCC, Assessment Report 5 (AR5), Working Group 2. (June 2010-date)
- Member, Editorial Board, *Water International*, Journal of International Water Resources Association (IWRA), USA (1998-2004)
- Prof. Satish Dhawan State Award for Engineering Sciences (2003), Govt. of Karnataka.
- CBIP Young Engineer Award (1993), for notable contribution in the field of Water Resources., Government of India
- Chairman, Water Resources Management, International Association for Hydraulic Research (IAHR) for the term, 2008-2011; Secretary, 2007-08; Member of the Section since April 2003.
- Member, Project Appraisal and Monitoring Committee (PAMC), Hydrology and Cryosphere, Ministry of Earth Sciences (June 2012 - date)
- Member, Programme Advisory Committee (PAC), Civil and Environmental Engineering, Science and Engineering Research Board (SERB), DST, (June 2012 - date)
- Member, Management Committee, Specialist Group on Climate Change and Adaptation, International Water Association (IWA), UK (2006-date)
- Member, Scientific Committee, SWITCH (Sustainable Water-management Improves Tomorrows Cities Health) project of the UNSECO, IHE-Delft, Netherlands (2006-date)
- Team Member, UNESCO team, to carry out a rapid assessment of the Kosi river floods on the Nepal side (Feb 2009)
- Steering Committee Member, Urban Flooding, National Disaster Management Authority (NDMA), Government of India. (2007-date)
- Member, Expert Committee, Manual on Urban Storm Water Drainage, Ministry of Urban Development, Government of India (2008-date)
- Expert Member, Review Committee for the UN-Sponsored project on "Vulnerability Assessment of Freshwater Resources in South and Southeast Asia" Asian Institute of Technology, Thailand, September 2007.
- Guest Editor (with Young-Oh Kim), Special Section, "Climate Change and Water Resources", Current Science, Vol. 98, 2010.

## Relevant Recent Publications

### Book

P. P. Mujumdar and D. Nagesh Kumar. (2012) *Floods in a Changing Climate: Hydrologic Modeling*, International Hydrology Series, Cambridge University Press, Cambridge, U.K., ISBN-13: 9781107018761

### Journal Papers

Arpita Mondal and Mujumdar, P.P. (2012), On the Basin-scale Detection and Attribution of Human Induced Climate Change in Monsoon Precipitation and Streamflow , *Water Resources Research*, Vol. 48, W10520, doi:10.1029/2011WR011468.

Mujumdar, P.P. (2012), Climate Change: A Growing Challenge for Water Management in Developing Countries, *Water Resources Management*, DOI 10.1007/s11269-012-0223-x.

Raje, D., and Mujumdar, P. P. (2010), “Hydrologic drought prediction under climate change: Uncertainty modeling with Dempster-Shafer and Bayesian approaches.” Advances in Water Resources, doi: 10.1016 / j.advwatres.2010.08.001 (Pub: Elsevier, Netherlands)

Raje, D., and Mujumdar, P. P. (2010), "Constraining uncertainty in regional hydrologic impacts of climate change: nonstationarity in downscaling", *Water Resources Research,* Vol. 46, W07543, doi:10.1029/2009WR008425, 2010 (Pub : American Geophysical Union)

Raje, D., and Mujumdar, P. P. (2009), "Reservoir performance under uncertainty in hydrologic impacts of climate change", *Advances in Water Resources*, Volume 33, Issue 3, March 2010, Pages 312-326doi:10.1016/j.advwatres.2009.12.008 (Pub: Elsevier, Netherlands)

Raje, D., and P. P. Mujumdar (2009). “A conditional random field–based downscaling method for assessment of climate change impact on multisite daily precipitation in the Mahanadi basin”, *Water Resources Research* (Pub: American Geophysical Union) 45, W10404, doi:10.1029/2008WR007487.

Mujumdar, P. P., and S. Ghosh (2008), “Modeling GCM and scenario uncertainty using a possibilistic approach: Application to the Mahanadi River, India”, *Water Resources Research,* (Pub: American Geophysical Union) 44, W06407, doi:10.1029/2007WR006137.

# Ashu Jain

**Contact**:

Professor, Department of Civil Engineering

Indian Institute of Technology Kanpur, Kanpur - 2018 016, UP

E-mail: ashujain@iitk.ac.in; +91 512 259 7411(O)7395(Fax)

**Education**:

Ph.D. (1994) Civil, University of Kentucky, Lexington, KY, USA

M. Tech (1990) Civil Engineering, IIT Bombay, India

B.E. (1988) Civil Engineering, Malaviya Regional Engg. College, Jaipur, India

**Selected Sponsored/Consultancy Projects (as PI Only):**

1. A Study for the self sustainability of a water body proposed in the Janeswar Mishra Lucknow Park, Sponsored by Lucknow Development Authority, Lucknow, UP, Amount Rs. 724,426.
2. Monsoon rainfall forecasting using neural networks, Sponsored by Department of Science and Technology, Government of India, New Delhi, Amount Rs. 15,90,000, No. DST/CE/20090172.
3. Groundwater pollution source identification using neural networks, Sponsored by Defense Research and Development Organization, Govt. of India, New Delhi, Amount Rs. 14,58,400, No. DRDO/CE/20060265.
4. Investigation of local scour at bridge piers under pressure flow conditions, Sponsored by Ministry of Water Resources, Govt. of India, New Delhi, Amount Rs. 13,50,000, No. MOWR/CE/20050298.
5. Hydraulic model study of Ghaghra River near Kamariaghat using remote-sensing, computer and physical modeling, World Bank Project Sponsored by PCC Services, Lucknow, UP, Amount Rs. 8,43,560, No. PCC/CE /20020179.

**Research Guidance**:

| | |
|---|---|
| Doctor of Philosophy: | 03 completed, 04 on-going |
| Master of Technology: | 30 completed, 02 on-going |
| B. Tech. Projects: | 13 completed |

**Selected Research Publications:**

1. Maier, H.R., Jain, A., Dandy, G.C., and Sudheer, K.P., Methods used for the development of neural networks for the prediction of water resources variables in river systems: Current status and future directions, Env. Mod. Software, 2010, vol. 25(8), pp.891-909.
2. Jain, A. and Kumar, S., Dissection of trained neural network hydrologic model architectures for knowledge extraction, Wat. Resour. Res, 45, W07420, 2009, doi:10.1029/2008WR007194.
3. Jain, A. and Kumar, A.M. , Hybrid neural network models for hydrologic time series forecasting, J. Applied Soft. Computing, 7(2), 2007, pp.585-592.
4. Kumar J., Jain, A., and Srivastava, R., Neural network based solutions for locating groundwater pollution sources, Hydrology J., 29(1-2), 2006, pp.55-66.
5. Jain, A. and Srinivasulu, S., Integrated approach to modelling decomposed flow hydrograph using artificial neural network and conceptual techniques, J. Hydrol., 317(3-4), 2006, pp.291-306.
6. Jain, A., Srinivasulu, S., and Bhattacharjya, R., Determination of an optimal unit pulse response function using real-coded genetic algorithm, J. Hydrol., 303(1-4), 2005, pp.199-214.
7. Jain, A. and Srinivasulu, S., Development of effective and efficient rainfall-runoff models using integration of deterministic, real-coded genetic algorithms, and artificial neural network techniques, Water Resour. Res., 40(4), W04302, 2004, doi:10.1029/2003WR002355.
8. Jain, A., Sudheer, K.P., and Srinivasulu, S. , Identification of physical processes inherent in artificial neural network rainfall runoff models, Hydrol. Processes, 118(3), 2004, pp. 571-581.

**Awards and Honours**:

1. Awarded *Endeavour Executive Award 2009* by Ministry of Education, Australia
2. Awarded *International Centre of Excellence in Water Resources Management (ICE WaRM) Fellowship* 2008 to visit The University of Adelaide, Adelaide, Australia
3. Awarded *Royal Society Fellowship* 2005-06 to visit The University of Leeds, Leeds, UK
4. Awarded *Best Discussion Paper Award 2005* by ASCE
5. *Fellow* of the Indian Water Resources Society
6. *Fellow* of the Indian Society for Hydraulics

**Vimal Mishra [**Wilson Ceramic Lab, Box 352700**,** University of Washington , Seattle, 98195**,** Email: vmishra@hydro.washington.edu, Phone: 206-661-8562]

**PROFESSIONAL PREPARATION**

**Purdue University, West Lafayette, IN**

Doctor of Philosophy in Agricultural and Biological Engineering (May, 2010)

**Indian Institute of Technology (IIT), Kharagpur, India**

Master of Technology (M.Tech.) in Water Resources Development and Management (June, 2005)

**C.S. Azad University, Kanpur, India**
Bachelor of Technology (B.Tech.) in Agricultural Engineering (June, 2003)

**APPOINTMENTS**

**Assistant Professor** (June 2012 onwards)
Indian Institute of Technology, Gandhinagar
**Post Doctoral Research Associate** **(**May, 2010-May 2012)
Advisor- Dennis P. Lettenmaier
Civil and Environmental Engineering, University of Washington, Seattle, WA
**Graduate Research Fellow** **(**August, 2006-May, 2010)
Advisor- Keith A. Cherkauer
Agricultural and Biological Engineering, Purdue University, West Lafayette, IN

**RELEVANT PUBLICATIONS**

**Mishra, V.**, B. V. Smoliak, D. P. Lettenmaier, J. M. Wallace (2012), A Prominent Pattern of Year-to-Year Variability in Indian Summer Monsoon Rainfall, Proceedings of National Academy of Sciences (PNAS), doi:10.1073/pnas.1119150109.

**Mishra, V**., F. Dominguez, and D. P. Lettenmaier (2012), Urban precipitation extremes: how reliable are the regional climate models?, Geophysical Research Letters, doi:10.1029/2011GL050658 (**AGU's most popular paper, highlighted in Science Magazine**).

**Mishra, V**., and D. P. Lettenmaier (2011), Climatic trends in major U.S. urban areas, 1950–2009, Geophysical Research Letters, 38, 8 PP., doi:201110.1029/2011GL048255 (**AGU's most popular paper**).

**Mishra, V**., and K. A. Cherkauer (2010), Retrospective droughts in the crop growing season: Implications to corn and soybean yield in the Midwestern United States, Agricultural and Forest Meteorology, 150(7-8), 1030–1045 (**Wide Media Coverage**).

**Mishra, V**., and K. A. Cherkauer (2011), Influence of cold season climate variability on lakes and wetlands in the Great Lakes region, Journal of Geophysical Research, 116(D12), D12111.

**Mishra, V**., K. A. Cherkauer, and L. C. Bowling (2010a), Changing thermal dynamics of lakes in the Great Lakes region: Role of ice cover feedbacks, Global and Planetary Change, 75, 155-162

**Mishra, V**., K. A. Cherkauer, and L. C. Bowling (2010b), Parameterization of Lakes and Wetlands for Energy and Water Balance Studies in the Great Lakes Region, Journal of Hydrometeorology, 11(5), 1057–1082.

**Mishra, V**., K. A. Cherkauer, and S. Shukla (2010c), Assessment of drought due to historic climate variability and projected future climate change in the Midwestern United States, Journal of Hydrometeorology, 11, 46-68

**Mishra, V**., K. A. Cherkauer, L. C. Bowling, and M. Huber (2011), Lake Ice phenology of small lakes: Impacts of climate variability in the Great Lakes region, Global and Planetary Change, 76, 166-185

**Mishra, V**., K. A. Cherkauer, D. Niyogi, M. Lei, B. C. Pijanowski, D. K. Ray, L. C. Bowling, and G. Yang (2010d), A regional scale assessment of land use/land cover and climatic changes on water and energy cycle in the upper Midwest United States, International Journal of Climatology, 30(13), 2025–2044.

## RESEARCH INTERESTS

Climate Variability, climate change, extreme events, surface water hydrology, global food and water security, hydrologic modeling, remote sensing of land and water resources

## MEDIA COVERAGE

Science Magazine, Bulletin of American Meteorological Society (BAMS), Purdue University, Fox News, Progressive Farmer, Hoosier Ag Today, Agriculture Online

## AWARDS AND HONORS

Lynn Graduate Fellowship, Purdue University
Purdue Climate Change Research Center Fellowship, Purdue University
German Academic Exchange Fellowship (DAAD)
German Academic Exchange Fellowship (DAAD) International Summer School
International Max Plank Fellowship
University gold medal, C.S. Azad University
Silver Medal, IIT, Kharagpur
Incentive Proposal Grants (Purdue University)
Travel Grant, World Climate Research Program's (WCRP) Reanalysis conference
Travel Grant, Graduate Climate Conference
Proposal Reviewer, National Science Foundation (NSF), USA
Journal Paper Reviewer (more than 20 international journals including Water Resources Research, JGR, Environmental Research Letters, Journal of Hydrology, Journal of Climate, Journal of Hydrometeorology)

## COLLABORATORS

Laura Bowling (Purdue), Matt Huber (Purdue), Indrajeet Chaubey (Purdue), Melba Crawford, (Purdue) R.S. Govindaraju (Purdue), Dev Niyogi (Purdue), Chris Funk (UCSB), Francina Dominguez (U.of Arizona), Brian V. Smoliak (UW), J. M. Wallace (UW), Deepak Ray (U. Minn), Brian Pijanowski (Purdue), Erkan Istanbulluoglu (UW), Nathalie Viosin (PNNL)

## FUNDED PROPOSALS (as Key Personal)

NASA, Multisensor/Multiscale Assessment of Urban Impacts in the Great Lakes Region, 2006-2010, Graduate Research Assistant, PI- Laura Bowling
DOE, Precipitation Extremes in Changing Climate: how much information regional climate model can provide? 2010-2013, key personal, PI- Francina Dominguez and Dennis P. Lettenmaier

NOAA, Development of the National Hydrologic Prediction System (NHPS), 2009-2012, key personal, PI- Dennis P. Lettenmaier
DOE, Streamflow data assimilation for short-term streamflow forecast, 2010-2013, key personal, PI- Dennis P. Lettenmaier
Purdue University, "Proposal for Funding to Establish Graduate Student Organization in the Agricultural and Biological Engineering Department at Purdue University" to College of Engineering, Purdue University (2008, funded $2500) , Co-I
Purdue University, Incentive grants (2007, 2008, $1000), PI

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Education

- **PhD, 1999** (Hydraulic and Water Resources Engineering), **Gauhati University, Gauhati, India**
- **Master of Engineering, M.E., 1988 (Watershed Management and Flood Control), Assam Engineering College, Gauhati University, India**
- **Bachelor of Engineering,** B.E., **1985** (Civil Engineering), **Jorhat Engineering College**, **Dibrugarh University, India**

Date of Birth: **24th January 1963**

Teaching Experiences

Has 23 years of teaching experience in various academic institutions, which includes 13 years at IIT Guwahati, Assam, India.

**Industrial/ Field Experiences**

15 years of field experience in hydrographic survey and river training work in the river Brahmaputra, Ganga, Mekong and their tributaries in connection with various consultancy works taken up for projects related to river training and water resources development and management, [1996-2013].

**Student project guided**

42 M.tech and 4 Phd Thesis guided so far and 6 more PhD student are working.

**Sponsored and Consultancy Projects**

17 sponsored projects and 31 consultancy projects from India and Abroad has been completed.

**Publications**: **82 technical papers published in Journal, book and Conference**

Some relevant publications:

1. Maya R. R. and Sarma A.K., Minimizing Diurnal Variation of Downstream Flow in Hydroelectric Projects to Reduce Environmental Impact, Journal of Hydro-environment Research, 2011, 5, 177-185.
2. M.D. Saikia and Sarma A.K. Numerical Simulation of Flow And Morphological Evaluations In Rivers Under Dam-Break Flows**,** International Journal of Modelling and Simulation, 2010, Vol. 3., (DOI: 10.2316/Journal.205.2010.3.205-4913)
3. Ahmed J.A and Sarma A.K., Artificial Neural Network Model for Synthetic Streamflow Generation, Journal of Water Resources Management, Springer, July 2007, Vol. 21, pp.1015-1029.
4. Sarma A.K., Giraud G., Baishya M.D., Rainwater Harvesting for Urban Flood Peak Reduction, My Green Earth-a Journal of Society for Socio Economic Awareness and Environment Protection, SSEAEP, Dec 2006, Vol. 3, No. 2, pp 14-21
5. Saikia M.D. and Sarma A.K., Numerical Simulation Model for Computation of Dam Break Flood in Natural Flood Plain Topography, Journal of Dam Engineering, IWPC, June 2006, Vol. XVII, No.1, pp. 31-50
6. Ahmed J.A and Sarma A.K., Genetic Algorithm for Optimal Operating Policy of a Multipurpose Reservoir, Journal of Water Resources Management, Kluwer, April 2005, Vol.19, Number 2, pp.145-161.
7. Bhakal L., Dubey B., Sarma A.K., Investigation of River Bank Erosion in Brahmaputra Near Agyathuri by Using GIS, Journal of Indian Society of Remote Sensing, March 2005, Vol. 33, No.1, pp 81-84
8. Sarma A.K. and Ahmed J.A., An Improved Numerical Integration Method of Computing Flow Profile, Journal of IWRS Oct 2004, Vol. 24 No.4, pp 1-8.

9. Sarma A.K. and Das M.M, Analytical Solution of Flood-Wave Resulting from Dike Failure, Journal of Water and Maritime Engineering, ICE, March 2003, Vol. 156, pp. 41-45.
10. Sarma B and Sarma A.K. Impact of Embankment System on Water Bodies of Majuli Island: A GIS Based Study, in the book Sustainable Water Resources Management and Impact of Climate Change, BS Publications, Hyderabad-500095, 2010, pp 333-343, ISBN : 978-81-7800-226-2
11. Sarma A.K. and Goswami P., Developing Intensity Duration Curve with Limited Rainfall Data, Jain Brothers, New Delhi, November 2006, pp. 187-194
12. Sarma A.K., Hydraulic Structures-chapter 12 in the book The Brahmaputra Basin Water Resources, Kluwer Academic Publisher of Netherland, March 2004, pp. 261-273
13. Mukherjee A and Sarma A. K. 2D flow simulation in alluvial river using MIKE software: A modeling approach, Lambert Academic Publishing. Printed in UK. ISBN: 978-3-8443-8408-6
14. Sarma A.K. and B. Sarma Optimal Ecological Management Practices for Minimizing Impact of Climate Change and Watershed Degradation Due to Urbanization, presented in the Seventh International Conference on Interdisciplinary Social Science 2012, 25th to 28th June, Barcelona, Spain.
15. Sarma A.K Assessment of Carrying Capacity for Hilly Urban Areas: Applicability of the Concept at the Ground Level, Thematic paper , CD Proceedings of International Conference ENSURE 2012, 24-26 Feb,2012.
16. Vinnarasi R. and A. K. Sarma, Climate Change Consideration in Planning and Development of Semi Urban Area, CD Proceedings of International Conference ENSURE 2012, 24-26 Feb, 2012, PID 280
17. Vinnarasi R. and A. K. Sarma *Statistical downscaling of GCM for predicting seasonal rainfall with short duration historical data* Proceedings of 2nd International Conference ICAMB 2012, 9th-11th January 2012, pp-1622-1626.
18. Maya R. Ray and A. K. Sarma, *Importance of input parameter selection for synthetic streamflow generation of different time step using ANN techniques*. Proceedings of International Conference on Neural Computation Theory and Application, NCTA 2011, 24th -27th October, Paris Franc, ISBN: 978-989-8425-84-3., pp-211-217.
19. B. Sarma, A. K. Sarma and C Mahanta: Optimal Ecological Management Practices (EMPs) For Controlling Sediment and Water Yield from Hilly Urban Watersheds. Proceedings of International Conference on Advances in Materials and Techniques for Infrastructure Development (AMTID 2011), NIT Calicut, India, 28 – 30 September 2011.
20. B. Sarma, **A K Sarma** and C Mahanta: *Geographic Information System for Environmental Management of Large River Systems*, Abstract Book of International Conference on the Status and Future of the World's Large Rivers, 11 to 14 April 2011, Vienna, Page No: 110, ISBN: 978-80-7399-518-8
21. Ray R.M., and **Sarma A.K.** "*Artificial Neural Network Based Synthetic Stream Flow Generation Model*", Proceeding of 3rd International Conference on Current and Future State of Water Resources and Environment" Organized by EWRI of ASCE and IIT Madras, Chennai India, 5th - 7th January 2010, pp.000942-52
22. Ray R.M. and **Sarma A.K**., "*ANN Based Synthetic Streamflow Generation Model*", Proceedings of National Conference on Recent Advances in Hydrology for Water Resources Development and Management, 2009, 21-22 January, WREMI, Vadodara , India.
23. Saikia, M.D and **Sarma A.K.,** "*Dam Break Flood Disaster Management and Damage Estimation*", Proceedings of Indian Engineering Congress, Dec 21-24 2006, Guwahati, pp- 102-111.
24. Saikia, M. D. and **Sarma A. K.,** 2006 "*Simulation Modeling for Planning and Management of River Basins under Flood Disaster*" Proceedings of An International Perspective on Environmental and Water Resources, December 18-20, 2006, New Delhi, India, EWRI, ASCE

## Member of Professional Bodies

a. Member of American Society of Civil Engineers (ASCE)
b. Life Member of Indian Society for Technical Education (ISTE)
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d. Life member of Institution of Engineers India (IEI)
e. Life member of Indian Remote Sensing Society (IRS)
f. Member of Indian National Committee for Climate Change (INCCC)
g. Member of Technical Advisory team of ADB TA project for Flood and Draught Risk Mitigation of Great Mekong River Basin Covering Cambodia, Vietnam, Thailand and Laos.
h. Member of National Coordination Committee of National Institute of Hydrology

i. Member of the Advisory Board, National Water Academy, Pune(2011-12)
j. Member of the Steering Committee on Urban Flood (National Disaster Management Authority, India)
k. Member of Steering Committee for National River Conservation (MoEF)
l. Member of Regional Co-ordination Committee for Centre for Flood Management Studies (CFMS), (NIH)